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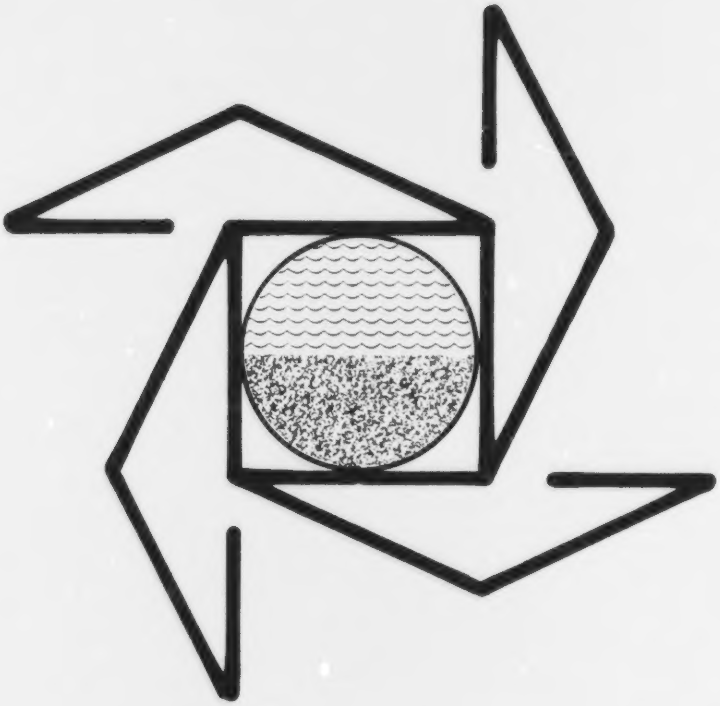
(CONFERENCE)
MAY 22-23, 1978
CHICAGO, ILLINOIS



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16. ABSTRACT

This report is a compilation of papers presented at the "Voluntary and Regulatory Approaches for Nonpoint Source Pollution Control" conference held at the Sheraton O'Hare Motor Hotel in Rosemont, Illinois May 22 and 23. 1978. Principal investigators of four section 108 (a) demonstration projects presented water quality data, sediment and erosion data, land management practices used on projects to evaluate impact on water quality, educational programs to inform the public of nonpoint source problems, and institutional arrangements that can be used to implement nonpoint source pollution controls.

Federal, State and County officials discussed NPS problems.

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FOR
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(Water Quality Planning)

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FOR
NONPOINT SOURCE POLLUTION CONTROL
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WELCOME

BY

DR. EDITH J. TEBO, DIRECTOR
GREAT LAKES NATIONAL PROGRAM OFFICE
U.S. EPA, REGION V
CHICAGO, ILLINOIS 60604

I am happy to welcome you to this conference which we have entitled "Voluntary and Regulatory Approaches for Nonpoint Source Pollution Control." We will share with you, today and tomorrow, considerable discussion on nonpoint source pollution control as it relates to the Clean Water Act, PL 92-500 and its 1977 Amendments. The agenda for this conference provides for an overview of the Nonpoint Source Pollution Control mandate to the U.S. Environmental Protection Agency through PL 92-500.

Nonpoint source pollution is recognized internationally as a problem, and is being addressed in the Great Lakes under the United States-Canada Great Lakes Water Quality Agreement. One of the references of this water quality agreement is directed to inventory land-use activities and their effects on the Great Lakes. To do this, we implemented four land-use pilot watershed studies in the United States and six watershed studies in Canada to prepare the information and remedial-measures recommendations to best reduce and control nonpoint source pollution to the Lakes. Region V has committed $13 million to support the Section 108(a) demonstration projects and land-use watershed studies. Additional funds have been and will be awarded through Section 208 grants to plan and implement nonpoint source pollution controls. Summary reports on the land-use watershed studies findings are available at the IJC Regional Office in Windsor, Ontario, Canada. The comprehensive reports will be available late this summer.

Russell Train, our former EPA administrator, stated in a speech in Bettendorf, Iowa, that nonpoint sources of water pollution, such as runoff from croplands; urban stormwater; and strip mining, are becoming the single most important water quality problem. Douglas Costle, our present EPA Administrator, stated in a recent speech to the National Association of Conservation Districts at Annaheim, California, that "Silt and sedimentation are the biggest sources of pollution in this country."

Congress placed primary responsibility for the management of nonpoint source pollution in the hands of the States. This is as it should be. States and local units of government are better able to identify their problems as part of their over-all planning process than is the Federal government. We want to see local government, acting on a regional basis, getting more and more into the business of really facing up to these issues. Plans for solving such problems would be created and carried out through a political process in which both citizens and their elected officials--not experts or appointed officials--make all the basic choices and decisions. We want to encourage State and local governments to tell us at the Federal level how we can help with programs that are conceived and implemented at lower levels.

To highlight some problems associated with nonpoint pollution, let me give you some examples:

1. Two billion tons of sediment are delivered to lakes and streams annually from over 400 million acres of croplands, as well as large amounts of nitrogen from fertilizers, phosphorous from nonpoint sources, animal wastes from feedlots, and toxic pesticides.

2. Between 5 and 10 percent of the total sediment load is estimated to come from 10 to 12 million acres of commercial forest harvested per year.

3. Strip mining, which affects about 350,000 acres annually, results in the discharge of millions of tons of acidity and sediment.

4. Urban sprawl, which consumes hundreds of square miles per year, generates sediment at an even greater rate than agricultural activities.

5. The runoff of stormwater in urban areas accounts for pollution of waters with large amounts of toxic and oxygen-demanding materials.

Nonpoint sources of water pollution have become more than 50 percent of the total water quality problems. As site-specific sources of pollution are reduced by municipalities and industries, other sources gain in relative importance.

The technical information to be reported to you today comes from four of our Section 108(a) Great Lakes demonstration grant projects. The principal investigators will discuss their work and their findings with us, and try to answer any questions that you may desire to ask. The information presented here today, hopefully, will provide you with a clearer understanding of the nonpoint source problems confronting us. We will report to you some methods and best management practices that have been successfully demonstrated to reduce and control the problem.

There will be two movie films shown during this conference that identify nonpoint source problems and offer some solutions. These films cover the geographic area of the continental United States. Descriptive brochures on the films entitled "Nonpoint '83" and "Runoff; Land Use and Water Quality" are available at the registration desk.

There are copies of the Black Creek Project final technical report available at the back table along with other informational brochures for your use.

I hope the papers presented today will benefit you in your planning activities. I appreciate your attendance at this conference. If we can be of assistance to you during the day, please contact Mr. Ralph Christensen or Ms. Peggy Harris, who will be happy to help you.

THE CLEAN WATER ACT AMENDMENTS OF 1977, PL 95-217

ENVIRONMENTAL PROTECTION AGENCY HEADQUARTERS PERSPECTIVE

by

Nathan Chandler*

I am very pleased to have this opportunity to give you the EPA perspective on the 1977 Clean Water Act Amendments as they relate to voluntary and regulatory programs for nonpoint source pollution control. As my boss, Administrator Douglas Costle, pointed out in December to the National Association of Conservation Districts, EPA is giving greater attention than ever before to nonpoint source pollution control. The reason for this is quite simple. As industrial and municipal point sources of pollution are brought under control, the nonpoint sources become a larger proportion of the total water quality problem.

In addition, EPA is very much concerned that nationwide estimates show a yearly loss of between 9 and 12 tons of topsoil per acre, the irretrievable loss of 1.5 to 2 million acres of farmland to urbanization, and the likelihood that by the year 2000 our present consumption of water will have to double to a staggering one trillion gallons per day. I mention these grim statistics at this meeting because water quality control and resource conservation are intimately linked. One goes hand in hand with the other.

Having said a word about the linkage between pollution and conservation, I'd like now to make a few generalizations about the clean water act amendments and then talk about some new EPA initiatives.

The Clean Water Act of 1977, Amending the 1972 Act, was a mid-course correction. It reaffirmed our national goals of achieving fishable and swimmable waters by 1983 and zero discharge of pollutants by 1985. Section 101 reaffirmed four basic national policies.

1. The prohibition of the discharge of toxic pollutants in toxic amounts.

2. Federal financial assistance for the construction of publicly-owned treatment works.

3. The development and implementation of areawide waste treatment management planning and implementation processes adequate to control pollutants in each state.

4. The continuing need to develop the necessary technology for water pollution control.

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*Nathan Chandler, Agricultural Advisor to U.S. Environmental Protection Agency's Administrator, Douglas M. Costle, Washington, D.C. 20460

The 1977 Amendments seek to sharpen EPA's four policy areas more effectively in order to reach our National goals. Toxic substances, included in both the clean water act and the Toxic Substances Control Act of 1976, are going to be more closely regulated. In fact, under TSCA, EPA is empowered to control the manufacture, sale, and distribution of dangerous toxic substances to totally prevent their entering the environment.

Federal financial assistance for the construction of publicly-owned treatment works has been funded at approximately $5 billion a year for fiscal years 1978-82. Rather than having just one-third of the nation's muncipalities in compliance, as is true at present, this long-term funding should see a substantial majority in compliance by 1983. I think it is worth noting here that municipalities must give serious consideration to land treatment of wastewater and that municipalities that do use land treatment of wastewater, and that municipalities that do use land treatment will receive an additional 10 percent funding.

Our principal concerns today, however, focus on areawide waste treatment management planning processes, and on research and demonstration, as they apply to nonpoint sources of water pollution.

The regulatory authority for the control of nonpoint sources of pollution, as stated in section 201, is unchanged. EPA's mandate is a broad and, we trust, a creative and constructive one. Briefly, the language of the law says, and I quote, "It is the purpose of this title to require and to assist in the development and implementation of areawide waste treatment management plans ...to the extent practicable, waste treatment management shall be on an areawide basis and provide control or treatment of all point and nonpoint sources of pollution..."

Section 208 encourages and facilitates this areawide waste treatment management planning and implementation process. The big news, I think, is that despite the mixed record of 208, areawide planning and management have emerged substantially strengthened both in the law and in EPA's policies.

Congress made five basic changes to strengthen the 208 program. I am going to enumerate them first and then discuss each at greater length.

1. Time for Preparing Plans;
2. Areawide Waste Treatment Management;
3. Irrigation Return Flows;
4. Dredge and Fill Permit Program;
5. Agricultural Cost Sharing.

You'll be glad to know, I'm sure, that on all five counts the news is good. Now let me expand and explain.

In regard to the timing of areawide planning--that is, 208--any statewide agency designated as the appropriate agency after 1975, which received its first grant before October 1, 1977, shall receive a grant of 100 percent for the first two years, and have three years after the receipt of the initial grant to prepare an initial plan. In short, the amendments reward previous accomplishments and hard work. Tom Jorling, head of EPA's water program, has reaffirmed the agency's commitment to those 208 agencies which have performed, and he has served notice that those which do not perform will not continue to receive EPA backing.

The key to effective planning is the assiduous cultivation of the kind of broad public participation that assures that areawide planning _is_ areawide in fact as well as in name. Also, EPA will be looking for plans that identify the major problems and propose appropriate solutions for those problems. It is essential not only that we get more bang for the buck, but we do not waste time and money tilting at windmills.

Now, when it comes to areawide waste treatment management, each 208 plan must include an identification of open space and recreation opportunities expected from improved water quality, including potential use of lands associated with treatment works. Once again, the Congressional and EPA thrust is to go beyond clean-up to, if you will, a sort of resource recovery.

Before I leave this item, I'd like to say that EPA has just completed some excellent new materials on how the public can achieve full benefit from improved water quality, and how communities can take advantage of the new fishing, swimming, and recreation opportunities. In short, we're beginning to reach the point where our National goal of fishable and swimmable waters can be turned into a reality.

I'm sure you'll be glad to hear that the new amendments drop irrigation return flows from the definition of a point source and transfer them to the 208 areawide waste treatment planning program. However, States are not precluded from regulating irrigation return flows under the permit program.

In regard to dredge and fill permit programs, I'm sure you will also be glad to know that discharges from dredge and fill that are from normal farming and ranching activities, including the construction and maintenance of farm or stock ponds; irrigation and drainage ditches; certain roads; and other farming dredge and fill operations resulting from an approved 208 program, are exempt from the 404 permit requirements.

Finally, but certainly not least, is the development of agricultural cost sharing, sponsored by Senator Culver and operating as the rural clean water program. The Culver amendment does two major things: It provides funds and it ties tightly together 208 planning and implementation.

I think I would be doing this audience a disservice if I did not say that Congress is going to be watching very carefully to see if the financial inducements and the administrative mechanisms of the rural clean water program will justify new levels of funding.

These five changes made by the Congress were designed to increase substantially our, and your, effectiveness in improving water quality management programs in the nonpoint source area. Congress and EPA both recognize that because of the naturally occurring sediment and attached pollutants, and because of the difficulty of obtaining hard data due to the multiplicity of nonpoint sources of pollution, there are no numbers associated with nonpoint source pollution as there are with the point source permit program. Sometimes this has been construed as an invitation to do as you please. Nothing could be further from the truth.

If I made no other point today, I want to make it absolutely clear that EPA and the Congress are expecting an acceleration of the implementation of the 208 nonpoint program through the application of the best management practices to control the most critical water quality problems.

Just because it is difficult to measure the amount of sediment; nutrients; salts; pesticides; organics; pathogens; oil; grease; and thermal changes stemming from nonpoint sources, it does not now mean, as it sometimes has in the past, that nonpoint polluters can claim that it is the known point sources (which can be measured) that must bear the burden of regulation and cleanup. That just will not wash with Congress or EPA.

Like a compass which always points toward the north pole, the indicators of the water quality problem point to severe nonpoint problems. As a Nation, we cannot afford the luxury of further delay or absolutely precise solutions. The time to move forward is now.

There are a great many things that we do know about these problems. We do have the management techniques that can reduce the pollution potential of a great majority of nonpoint sources. For example, we know that if we manage more closely the timing, type, and amount of fertilizer and pesticides, as well as tillage practices, that we can reduce substantially the pollution potential of a farming operation.

Many farmers are using these successful management tools today. Tools which have been conceived and developed by farmers who want to make the best use of their limited soil and water resources, as well as the crops which are nurtured by these resources. These techniques are the best management practices which EPA requires in the nonpoint source portion of the water quality management plan.

Of course, best management practices vary from terrain to terrain and crop to crop, but that does not mean that they are not well known for every area of the country. Thus, I have no qualms in telling you that EPA's water quality management program is focusing on the accelerated application of these down-to-earth solutions to local problems with every expectation of substantial success. These best management practices are solutions which good managers have initiated and other good managers have adopted. In fact, it is because these best management practices have been widely accepted that EPA expects a voluntary program to evolve from most water quality plans.

However, where critical water quality problems are not dealt with, EPA favors having, as some six States have already done, a back-up nonpoint source regulatory program. I do not think there is any great need to dwell on that point. Most farmers recognize the necessity to protect their own investment, and are not about to sit quietly by while a few recalcitrant landowners imperil the success of the voluntary approach. EPA views farmers as concerned and informed businessmen and citizens, and, so, while a back-up regulatory approach may be necessary, a voluntary approach is preferred.

EPA is putting particular emphasis on three initiatives to speed up solving the worst nonpoint source water quality problems. The first is the model implementation program; the second, the rural clean water program, sometimes referred to as the Culver amendment; and the third is the integrated Federal water quality management program. I want to say a word or two about each of these programs and how each relates to the general nonpoint source problem.

The model implementation program has been designed to do three things:

- Help those areas which have identified water quality problems to move forward more quickly in implementing solutions.
- Identify major roadblocks, whether of a technical, legal, or social nature in the implementation process.
- Review EPA and USDA laws and authorities to see where changes may be necessary for more effective implementation of water quality management plans.

More than one hundred MIP applications were reviewed by States, EPA regions, and USDA/EPA national committees; from which seven were selected from different parts of the country. These seven are:

1. Indiana Heartland - Indiana
2. Maple Creek - Nebraska
3. West branch of the Delaware River - New York
4. Little Washita River - Oklahoma
5. Broadway Lake Watershed - South Carolina
6. Lake Herman - South Dakota
7. Sulphur Creek - Washington

There is one essential element common to these seven model implementation projects--the various people involved, including State and local officials, as well as farmers, have agreed to agree. All concerned have recognized that the problem is of sufficient severity to demand concerted action. While everyone may not have agreed with the chosen solution, everyone did agree that cooperative, coordinated action was required. These model implementation programs are moving forward, and we expect to learn a good deal from all seven, which will prove of widespread usefulness in combatting similar tough problems.

The second EPA initiative, the rural clean water program, is the new program that will put into effect the agricultural cost-sharing portion of the Clean Water Act of 1977. This portion of the act authorizes The Secretary of Agriculture, with the concurrence of The Administrator of EPA, to establish and administer a program to enter into long-term contracts of not less than five years, nor more than ten years, with rural landowners and operators for the purpose of installing and maintaining best management practices to control nonpoint source pollution and to improve water quality.

Only those States or areas which have an approved agricultural portion of a 208 plan qualify for financial assistance. The agricultural problem, priorities, and the best management practices identified in the approved 208 plan determine which best management practices will be cost shared. The primary objective of the rural clean water program is to accelerate the implementation of nonpoint source control programs and the application of best management practices for high priority water quality problem area.

The last of the three initiatives, the integrated Federal water quality management program (Section 304(k) of PL 92-500) authorizes $100 million per year for fiscal years 1979-1983. This program is designed to serve as a catalyst in bringing Federal agency expertise to State and local agencies involved in critical water quality management problems. These funds will be used to accelerate ongoing Federal programs in areas which have been identified by 208 agencies as having significant water quality problems. Recognizing that the successful implementation of many 208 programs is dependent upon the expertise and support of Federal agencies, these funds could be used, for example, by the Cooperative Extension Service to assist in implementation of an educational program regarding nutrient use above a recreational lake where eutrophication is a problem.

I think you can see that these three programs--the Model Implementation Program, the Rural Clean Water Program, and the Integrated Federal Water Quality Management Program--are all aimed at accelerating the attainment of our National water quality goals.

I am sure that I don't need to remind this audience that 1983 and 1985 are just around the corner. The problem of time is one with which even the titans of the modern world have had to contend.

This reminds me of a story about Winston Churchill when he was Prime Minister of Great Britian during that nation's darkest hours. Churchill was speaking before a key group of military personnel. He was introduced not only as the Prime Minister of England, but as the only man who had drunk enough brandy to fill the hall in which Churchill was speaking to a hypothetical mark halfway up the wall. As the Prime Minister walked to the podium, shuffling his papers, he started his address by looking back at that hypothetical mark on the wall and said, "So much to do and so little time to do it in."

I would like to emphasize the fact that we recognize that nonpoint source problems are complex and widespread, and that we do not expect all such sources to be cleaned up quickly or completely. But we do intend to move ahead with all of our authorities without delay, employing the whole range of pollution control tools, including education; regulations; improved management; incentives; and voluntary programs. The most critical water quality problems will be addressed first; all fifty States are in this process. Most have identified agricultural activities as a major nonpoint source of pollution. In carrying out this program, EPA has encouraged voluntary programs reinforced by effective and reasonable back-up regulatory authority.

Thank you very much.

U.S. ENVIRONMENTAL PROTECTION AGENCY SAM-31 MEMORANDUM ON POLICY, GUIDANCE and APPROVAL CRITERIA FOR 208 WATER QUALITY PLANNING

by

Michael W. MacMullen*

Perhaps none of EPA's State and Areawide Program Memoranda (SAM's) has been so widely discussed, and so little understood as SAM-31. Many people active in some phase of the water quality management planning process have asserted that SAM-31 removes any substantial requirement for a regulatory program of nonpoint source (NPS) pollution control. For example, substantial discussion was had within the Legislature of one Region V State to the effect that since SAM 31 provided for voluntary NPS control programs, there was no compelling reason for the State to adopt even a minimal regulatory control program on its own initiative. As a result of these discussions a very promising sedimentation control regulation was removed from further legislative consideration. I believe that SAM-31 will come to be recognized as one of the most important policy statements on management control mechanisms for NPS of pollution which have yet been produced and distributed.

The basic thrust of SAM-31 is squarely to the heart of the matter: that Regulatory Programs are in fact required for NPS control, where these programs are determined to be the most practicable method of assuring that an effective NPS control program will be implemented. Determinations of practicability are to be based on economic, technical, social, and environmental factors coupled to an analysis of the historical effectiveness of any existing non-regulatory programs within the planning area. The 208 agency, in consultation with the Regional Administrator, is to determine the need for regulatory programs. Certainly, it should be pointed out, here at the onset that regulatory programs are not required where the plan prepared under Section 208 certified that substantial water quality problems resulting from NPS do not now exist and are not likely to develop in the foreseeable future.

In order to be approvable a proposed Regulatory Program must include the following elements:

1. Authority to control the problem which the program addresses.

2. Authority to require the application of Best Management Practices (BMPs).

3. Authority to implement appropriate monitoring and inspection activities.

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*Michael W. MacMullen, Chief, Water Quality Management Section, Planning Branch U.S. Environmental Protection Agency, Region V

4. Authority to implement the chosen control tools such as permits, licenses, contracts, etc.

5. Enforcement authority.

6. A designated management agency or agencies responsible for implementing the regulatory program.

Other approaches to nonpoint source control may be approved by the Regional Administrator as fulfilling the appropriate NPS control requirements only where in his judgment the program will result in achievement of the desired water quality goals. This means that the responsibility is imposed on the appropriate 208 Planning Agency to demonstrate, within the covers of the plan, that a non-regulatory program can and will work. Even then, full approval of non-regulatory programs will only be given where implementation efforts, such as hiring of personnel or budget allocations have actually commenced. If implementation is to occur in stages, and stage one has been implemented, and a definite schedule for implementing future stages has been agreed upon, full approval may be granted. In any event, approval is to be given only when the following conditions are met:

a. Identification of specific BMPs.

b. Agreement on a schedule of milestones, such as implementation, monitoring and program evaluation.

c. Provision of an effective educational program to inform the affected public of the requirements.

d. Provision of adequate technical assistance and financial assistance, if needed.

e. Agreement to reporting system (at least annual) to the Regional Administrator on progress made in implementation.

Approval of non-regulatory approaches is to be withdrawn, if the Regional Administrator determines that implementation milestones are not being met. These non-regulatory approaches will therefore be allowed to continue from one reporting period to the next only when continuing and substantial progress, including the application of BMPs is being made toward attaining water quality goals. Where such progress is not being made, approval of these non-regulatory approaches is to be reworked, and it will be presumed that a regulatory program is the most practical means of assuring program implementation.

The Regional Administrator is to disapprove a proposed NPS program as being inadequate for the NPS portion of the plan, when he has reason to believe it will not be effective and will not lead to the application of BMPs. Factors he should consider in taking this action should include the severity of the NPS problem, past experience of the involved governmental unit with the proposed approach, and the type of program that is proposed.

Where substantial water quality problems continue to exist, those programs which are merely a continuation of an existing program (i.e., which do not provide additional educational, technical, or financial assistance, or those which utilize techniques and institutions which have not been successful) which have been in place for a sufficient time to evaluate their effectiveness, shall not qualify as acceptable.

The finding by the Regional Administrator of an unacceptable NPS plan element can be expected to have a number of widespread impacts. In the first place, nothing is more contemporary to the American political scene as the complex interplay between taxation levels, regulation by government in general, and land use restrictions in particular. Rejection by EPA of wholly voluntary NPS control programs will undoubtedly be a highly visible and in some quarters, a highly controversial action. Some people may view the action, as a significant step in the direction of decreasing on the one hand, the individual's right to manage his or her own land as they see fit, while increasing on the other hand, the level of governmental control over private property. Additionally, disapproval of a NPS plan element may very well have serious, long term consequences as to the viability of the specific planning agency's continuing designation as a Section 208 agency for the geographic area in question. In any event, the implications of SAM-31 and its plan review and approval criteria are such that the fact of the immediate and long term significance of this policy memorandum does not appear open to serious question.

CONSERVATION DISTRICT INVOLVEMENT

IN

208 NONPOINT SOURCE IMPLEMENTATION
(NACD PERSPECTIVE)

by

James E. Lake*

As a representative of the National Association of Conservation Districts, I am very pleased to participate in this conference. Many conservation districts throughout our country, as well as NACD, have been very much involved in water quality planning, and expect to play a very significant role in implementing "Best Management Practices for Nonpoint Source Pollution Control," which is certainly a key issue at this conference.

The activities of conservation districts have been ongoing for more than forty years in the United States.

The conservation movement began in 1937 when model legislation was furnished to the States by President Roosevelt providing for the creation of conservation districts by State law. Since that time, all States; Puerto Rico; and the Virgin Islands have adopted such laws. Some three thousand conservation districts have been created throughout our Nation.

Most States' district laws provide for establishment of districts as political subdivision of the State. Although State laws governing conservation districts vary in some respects, their purposes are the same everywhere--that is, to focus attention on land, water, and related resource problems; to develop programs to solve those problems; and to enlist the support and cooperation from all public and private sources to accomplish district goals.

Conservation districts are managed by local citizens who know their local problems. Usually, districts have from five to seven officials who are either elected or appointed, depending on the laws of the particular State. There is a growing trend to provide for the election of these governing bodies at the general election. Over seventeen thousand men and women now serve as district officials. Originally, conservation districts primarily served agricultural co-operators--cities and towns not being included within most districts' boundaries. However, in recent years, conservation districts have either by amendment to the district laws, or by the redefining of district boundaries included the entire soil and water resource areas encompassing urban and city dwellers as well.

Most conservation officials are farmers and ranchers; however, they are being joined more and more in recent years by bankers, homeowners, sportsmen, businessmen, county officials, and many other citizens concerned

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about natural resources. An increasing number of States are requiring representation on district governing bodies by urban and nonfarm interest.

In every district, officials develop and continually maintain a long-range plan which contains facts about the soil, water, and related resource problems of their district. The long-range plan also outlines measures that can be taken to correct the problems identified. The long-range plans must continually be updated in order to provide current resource information that is needed to assess current problems and to provide a base for setting new priorities. All districts prepare an annual plan of operation to guide the current year's activities. To accomplish the goals spelled out in the long-range plan and the annual plan of operations, district officials have developed working agreements with many local, State, and Federal agencies.

Through a memorandum of understanding, districts receive Federal assistance from the United States Department of Agriculture's Soil Conservation Service to provide technical assistance to individual landowners and land users for palanning and installing conservation practices needed on their lands. Districts also have memorandums of understanding and cooperative arrangements with many other Federal, State, and local agencies.

There are now over two million district co-operators throughout the Nation. These co-operators have been working with conservation districts voluntarily to apply conservation practices (many are synonymous with Best Management Practices) on their land for the last forty years. However, with all these indications of success, the fact still remains that there is a tremendous job to be accomplished in soil and water conservation. New problems continue to arise, and millions of acres of our valuable cropland are still unprotected and are eroding at a rate accelerated by man's activities that will deplete the soil resource if it continues. Furthermore, the resulting sediment is recognized as the largest single polluter of our streams by volume. In addition, it is recognized that water quality can be further degraded by the excessive nutrients and pesticides carried by the sediment.

Just last year, the General Accounting Office reported on a survey of the effectiveness of conservation work throughout our country. The report indicated that the Soil Conservation Service estimated an average of nine tons of soil per acre per year was being lost from our Nation's croplands, and that a significant amount of cropland losing soil in excess of the tolerable soil loss limits has not been protected by the application of erosion control practices. In fact, the report indicated that 42 percent of the 335 million acres of cropland harvested in 1975 did not have adequate erosion control techniques applied.

In recent years, attention has turned toward the effects of erosion and related pollutants on water quality. Several major events over the past few years have led to the involvement of conservation districts in 208 water quality planning. In 1970, a National Sediment Conference identified sediment as a serious polluter of our Nation's waters. Conservation districts became more concerned about those water quality problems that might be created by agricultural activities. In 1972, the National Association of Conservation Districts, EPA, the Council of State Governments, SCS, and others worked to develop a Model State Act for Soil Erosion and Sediment Control, to be considered throughout the country. The Model Act was published by the Council of State Governments in its 1973 Suggested State Legislation. Following this, NACD received a grant from EPA to assist individual States to hold sediment control institutes. The purpose of these institutes was to discuss the problems related to sedimentation and water quality; to discuss potential legislation and sediment control programs that could be implemented to reduce these problems; and to educate individual district officials as to the seriousness of erosion, sediment, and related water quality problems. Fourty-five sediment institutes were held in cooperation with State Soil and Water Conservation agencies, SCS, and State associations.

As of 1977, 15 States, the Virgin Islands, and the District of Columbia had adopted various forms of sediment control legislation. The legislation in these States is quite diverse and may vary a great deal from the model legislation introduced in 1972. However, the control of erosion and sediment is an important feature of all of these laws.

A brief summary of the sediment control laws in three of these States follows:

Virginia

The efforts of Virginia's Soil and Water Conservation Commission and the Erosion and Sediment Control Task Force of the Governor's Council on the Environment in 1971-1972 resulted in the 1972 enactment of a bill for erosion and sediment control on land disturbing projects other than agricultural or silvicultural.

The purpose of the law was to establish and implement a statewide, coordinated program to control erosion and sediment, and to conserve and protect the land; water; air; and other natural resources of Virginia. The State Soil and Water Conservation Commission was assigned responsibility for administering the law.

Guidelines, standards, and criteria were adopted by the Commission and became effective July 1, 1974. Local control programs consistent with the State program are developed and carried out by (1) the soil and water conservation district; (2) where appropriate, by counties, cities, and incorporated towns; or (3) by a joint venture between a district and a county, city, or town. These local programs are approved by the Commission.

If any county, city, town, or district fails to fulfill these requirements, the Commission develops and adopts a program to be carried out by the district, or if there is no district, by the county, city or town.

The local programs require an erosion and sediment control plan approved by the local government before land disturbing activities can begin. The local authority can require an applicant to insure that emergency measures for appropriate conservation be taken at the applicant's expense. To insure this, the authority can require a letter of credit, cash escrow, performance bond, or other legal arrangement before issuing the permit.

Iowa

Iowa's erosion and sediment control law requires abatement of erosion when a complaint is filed with the commissioners of a conservation district, provides for adoption of soil loss limit regulations by districts, and provides for State financed cost-sharing for installing needed measures. Penalties are imposed when the landowner fails to initiate necessary work within specified time limits.

Iowa was the first State in which districts experienced this new responsibility governing agricultural lands. A key stipulation in the Iowa law is that cost-sharing and technical assistance must be available before a landowner can be required to install measures to meet the requirements of the law.

Maryland

Maryland's Statewide Sediment Control Act was adopted in 1970 by the Maryland General Assembly. The Department of Natural Resources is the responsible agency. The act requires that before land is cleared; graded; transported; or otherwise disturbed for any purpose (except agriculture and single-family dwelling construction), the proposed earth change shall first be submitted to and approved by the appropriate soil conservation district. State projects, Federal projects, or projects on State-owned lands are approved by the Department of Natural Resources. Under the act, each county and municipality is required to adopt grading and sediment control ordinances and have them approved by the Department of Natural Resources (DNR). All 23 counties and Baltimore City adopted ordinances by the end of 1972. The Maryland Attorney General has ruled that "Protective stormwater measures may be imposed by the Soil Conservation District" under the 1970 Sediment Control Law.

In 1972, when Congress passed amendments to the Clean Water Act, P.L. 92-500, it possibly enacted the most significant legislation involving conservation districts since their creation. Never before in the 40-plus years of conservation district activities in this country have the challenges and opportunity been greater than they are today as a result of Section 208 of that law. Section 208, as you know, requires that each State develop State or areawide plans for controlling pollution from both point and nonpoint sources. Nonpoint sources include such areas as agriculture, silviculture, surface-mined areas, and construction sites. Districts because of their experience became directly involved in nonpoint planning for these activities in many

States. Some of the key provisions of Section 208 that have provided the opportunity for district involvement are: the emphasis on local involvement, the requirement for identification of water quality problems by source, and the need for development of best management practices that will help solve the identified nonpoint source water quality problems. The provisions also require that the agency or agencies to manage the nonpoint program be designated by the governor. All of these provisions led very naturally to the involvement of conservation districts.

The language of Section 208 also spells out that the programs are to be carried out at the local and State levels, with local participation playing a major role in formulation and implementation of the 208 plans. Soil conservation districts are the key local agency for involving rural landowners and concerned citizens. As local landowners themselves, district officials provide the grass roots contact between government at all levels and the local people.

In addition, districts have perfected working arrangements which allow the integration of Federal, State, and local governmental agencies. Through this cooperation, conservation districts also have the technical expertise to provide landowners assistance in making decisions affecting nonpoint source pollution control on their land. They also have a tremendous amount of necessary resource information such as soil surveys, resource maps, conservation needs inventory data, soil loss information (Universal Soil Loss Equation) that is needed to identify the critical areas where water quality problems do exist.

In addition, districts with the technical assistance of SCS have the expertise to assist landowners with the development of plans outlining Best Management Practices on their lands. Many existing and well-known conservation practices that have been used for years, such as grassed waterways; terraces; erosion control structures; minimum tillage; pasture land management; and many others, are "Best Management Practices" whenever they are identified as the best known means of control for agricultural nonpoint source water quality problems addressed in a 208 plan. Just because we have developed a new term which describes those measures to be applied to solve water quality problems related to agriculture, it does not mean that we scrap all the existing technical methods that we have used in the past. Instead, we will be focusing on how to use our technical experience more efficiently in addition to searching out new methods of control which will also be recognized as "Best Management Practices" to improve water quality.

Districts have some real challenges to meet, and in some cases, changes to make in their own organization, in order to accomplish the objectives of the nonpoint source control efforts under Section 208. To meet these challenges, districts will need to, and are, reassessing their priorities. The days of the "first-come-first-serve" approach for assistance are numbered. Setting priorities for conservation planning and application is a responsibility of conservation districts. Not only is this an important aspect of 208 planning, but of ongoing district programs as well. The Soil Conservation Service has agreed to provide technical assistance in accordance with the priorities set by district officials. This means that technical assistance should, and will be, available to landowners and operators on a "worst-first" basis in the future. It will mean that instead of working with the most aggressive landowners who request assistance for relatively minor problems, the Soil Conservation Service and other district co-operating agencies, such as the Cooperative Extension Service, must concentrate on working with the less progressive operators who usually have the more difficult problems, but are more hesitant to request assistance. As a result of this approach, implementation will be accomplished in the critical areas first in order to have the greatest and most immediate impact on water quality.

With the growing responsibilities conservation districts are being asked to assume, the need for additional district administrative and technical staff is critical. In many States, county and State government provide funds to enable districts to fill at least part of this manpower need.

Federal personnel ceilings limit the number of SCS and other agency personnel available to districts. If some additional manpower needs can be met from State and local sources, better use of SCS technical assistance can be made in solving critical land protection and water problems.

Districts will need to continually improve their educational and informational programs in the future in order to show the need for additional support.

Districts are demonstrating their ability to make these adjustments as well as their ability to manage programs for the installation of Best Management Practices in several programs already underway in the country. The following programs are illustrative of districts' abilities to manage programs in the future. The three examples that will be briefly discussed are the Pennsylvania Clean Streams Program, the Montana National Streambed and Land Preservation Law, and the Black Creek Demonstration Project in Indiana.

Pennsylvania Clean Streams Program

Several developments in Pennsylvania revealed the need for an expanded program for erosion and sediment control. These included the erosion and sediment problems created by industrial development and urbanization; a growing interest in, and citizen support for, total watershed management programs; and the general recognition that sediment was the largest single pollutant, by volume, of water resources.

On September 21, 1972, following study by the Environmental Quality Board (EQB) and public hearings, rules and regulations for erosion and sedimentation control were adopted by the EQB pursuant to the existing Clean Streams Law. Under the regulations, all earth-moving activities, regardless of size, must have an erosion and sedimentation control plan. In addition to an erosion and sedimentation control plan, earth-moving activities greater than 25 acres must, with certain exceptions, have an erosion and sediment control permit from DER.

The Department of Environmental Resources developed an operating procedure that would utilize conservation district expertise in the program. The staffs of the Bureau of Water Quality Management, the Bureau of Soil and Water Conservation, and the Bureau of Litigation and Enforcement jointly developed this procedure.

On projects requiring departmental permits, an application for an erosion and sedimentation control permit is submitted to the conservation district along with an erosion and sediment control plan. The conservation district has 45 days during which to act upon the application. Following technical review, the conservation district board, at an official meeting, takes action to recommend to the department that a permit should either be issued or denied. This recommendation is forwarded to the department's regional office where the permitting process takes place.

Through a department policy established by the Secretary of the Department of Environmental Resources, the Bureau of Soil and Water Conservation is to provide technical support on erosion control matters to other bureaus within the Department. Inspection and enforcement activities are handled by the Office of Deputy for Protection and Regulation and Deputy for Enforcement within the Department. Included in the operating procedures is a provision that the Department may delegate portions of the enforcement program to local jurisdictions.

The resources management portion of the program has been assigned to the Bureau of Soil and Water Conservation and the 66 conservation districts. The Bureau's Division of Soil Resources and Erosion Control implements the Department's program through informational, training, administrative, and liaison activities. Districts provide information, planning assistance, plan review, and land-use monitoring assistance to the Department of Environmental Resources. Twenty-three districts have requested and have been delegated authority in the inspection portion of the program to date.

Montana National Streambed and Land Preservation Law

In 1975, the Montana Legislature passed the Natural Streambed and Land Preservation Act, referred to as S.B. 310. This law provides that conservation districts must review and approve all proposed projects which affect perennial streams such as channel changes, new diversions, rip rap, jetties, new dams and reservoirs, commercial; industrial; and residential developments, snagging, dikes, levees, debris basins, grade stabilization structures, bridges and culverts, recreation facilities, commercial agriculture, and certain farming; grazing; and recreation activities. Conservation districts have the option of modifying this list to meet local needs.

When a district receives a proposed project, the Department of Fish and Game (DFG) is notified. If the DFG or the district requests it, a review team consisting of representatives of the district, DFG, and the private landowner examines the site of the proposal. If agreement is not reached, the District Court is asked to appoint an arbitration board. Technical assistance is provided by the Soil Conservation Service to all members of the team.

Under S.B. 310, the conservation districts held hearings on their proposed rules and regulations. There was substantial publicity on the new program in the newspapers, the special articles appeared in farm and livestock magazines.

In 1976, the first year the law became effective, Montana districts processed some 2,000 proposals.

The Black Creek Study, Allen County, Indiana

The Black Creek study was undertaken in 1972 by the Allen County Soil and Water Conservation District as a result of a grant from the U.S. Environmental Protection Agency, Region V, Chicago. Technical assistance was provided by the Soil Conservation Service and research support was supplied by Purdue University, the Agricultural Research Service, and the University of Illinois.

The project demonstrated the ability of a Soil and Water Conservation District to efficiently administer an extensive program for nonpoint source pollution control. The reliance on the local conservation district for the administration was shown to be a very important aspect of public acceptance and voluntary participation.

The Allen County Conservation District also demonstrated the ability of a district to efficiently handle cost sharing funds and to carry out long term contracts with private landowners.

Some of the major points substantiated and highlighted by the Black Creek study were that:

* The cost of achieving treatment on every acre of land to improve water quality would be extremely high. It probably would not be physically possible regardless of cost; therefore, water quality improvement must be approached by treating the critical areas first. It is, therefore, obvious that the critical areas must be identified for any watershed before treatment efforts begin.

* Once critical areas are identified, Best Management Practices need to be selected for treating the critical areas. Best Management Practices for the Black Creek Watershed were identified by the District Board of Supervisors with assistance from the Soil Conservation Service staff. These included: field borders, grade stabilization structures, grassed waterways, livestock exclusion, pasture planting, sediment control basins, terraces, limited channel protection, and tillage methods which increase crop residue and surface roughness.

* Farm-by farm conservation plans were found to be essential in programs of water quality improvement. The plans should be simple in format and selective in approach. Obligations of participating farmers must be clearly delineated.

* A voluntary program with sufficient incentive payments and technical assistance can achieve significant land treatment aimed at improving water quality. Regulations or the threat of regulation may be required to achieve treatment on land owned by the relatively small number of nonco-operators.

* Traditional cost-sharing programs based on a fixed percentage payment for every practice are not adequate to sell best management practices for water quality improvement. While an overall average might be set, local districts should have the responsibility for setting the rate for individual practices within the limitations.

* Public information is critical to a successful land treatment program. Landowners and the general public should be kept up to date on all phases of a program from conception through planning to implementation.

A recent significant opportunity for district involvement in Best Management Practice implementation arises out of the new amendments to the Clean Water Act signed by the President on December 15, 1977. The agricultural cost-sharing section introduced by Senator Culver of Iowa authorizes $200 million in fiscal year 1979 and $400 million in fiscal year 1980 to be used for cost-share assistance for implementation of Best Management Practices in rural areas having significant nonpoint water problems identified in the 208 water quality plan.

The amendment passed the Senate and House with very little dissent. Districts are identified in the law as the local governmental agency responsible for determining (in cooperation with the Secretary of Agriculture) priority amoung individual landowners and operators requesting assistance to assure that the most critical water quality problems are addressed first, and for approving co-operators' plans outlining Best Management Practices to be installed on their land with cost-sharing pursuant to long-term contracts. This important legislation has specifically named conservation districts for direct involvement in carrying out the law.

The program which is being developed pursuant to this legislation will be called the Rural Clean Water Program. The Secretary of Agriculture has designated the Soil Conservation Service as the lead agency responsible for carrying out this program.

In order for landowners to be eligible for participation in the program, their land must be identified as part of the critical areas addressed in a 208 plan certified by the governor of that State and approved by EPA.

Since this program is directed at designated critical areas with significant water quality problems, it is necessary that priorities be set and funds assigned accordingly, both on a National and State basis. For this reason, not every district or county will be included in the program.

The Rural Clean Water Program provides four options to the Secretary of Agriculture through SCS for carrying out the program at the State and local levels. These include entering into agreements for administration of all or part of the program with:

1. Soil Conservation Districts, or

2. State Soil Conservation Agencies, or

3. State Water Quality Agencies, or

If none of the above, then

4. Transfer of funds from SCS to ASCS for administration of the program. Regardless of the option selected, district officials will be jointly responsible for setting the priorities for assistance as well as solely responsible for approving plans on which contracts for cost-sharing will be based.

Districts have been working with State and areawide agencies to develop the nonpoint source phase of 208 plans for some time now. In fact, in over half the States, the State conservation agencies are preparing the agricultural nonpoint plans under contracts from the State water quality agencies. In many other States, districts are actively assisting in the development of the agricultural nonpoint plan through cooperative agreements.

As a result of this participation and the fact that they have the expertise and working tools to accomplish implementation, conservation districts are being identified in many plans as the management agency for implementing the agricultural nonpoint plan.

In summary, the outlook for conservation districts, as a result of the 208 water quality effort, is excellent. The opportunity for districts to get conservation on the land has never been greater. The changes taking place in district operations are all positive changes toward meeting modern needs, more efficient use of resources; people; and tax dollars to protect both our soil and water resources.

THE WISCONSIN NONPOINT SOURCE POLLUTION ABATEMENT PROGRAM

JOHN G. KONRAD*

Water Quality in Wisconsin rivers and lakes have undergone considerable change over the last decade. Rivers which have been burdened by large loads of industrial waste are being improved through the construction of new treatment systems. Removal of domestic sewage through construction of new municipal waste treatment facilities and upgrading of existing plants has also improved water quality. Dissolved oxygen levels are increasing in many streams and fish are now present in waters where they could not survive 10 years ago.

However, the quality of snow melt and rain water from city streets and agricultural lands has not improved. Pollutional loads from urban areas have increased as a result of population increases and urban/suburban development. In rural areas, many agricultural conservation practices were developed to enhance productivity by minimizing the loss of top soil. With increased implementation of conservation practices, water quality benefits should be positive. This is not always the case. Funding for the cost sharing of these practices has decreased, and there has been a trend toward supporing practices which have a greater economic benefit for the farmer and generally a lower level of water quality control. Since records are not kept of the removal of conservation practices as land changes hands or as owners change cropping practices or convert to larger sized equipment, it is impossible to maintain an accurate assessment of the amount of land currently protected by conservation practices.

The 1972 amendments to the Federal Water Pollution Control Act set as a national goal to "maintain the chemical, physical and biological integrity of the nations waters" and to provide for "fishable and swimable conditions." One of the mechanisms established for achieving these goals was the Areawide Water Quality Management Planning process (Section 208). Since relatively little was known about the effects of land derived pollutants on water quality, the 208 program became the major means by which nonpoint source pollutants were to be assessed and remedial programs developed.

In Wisconsin, we have completed over four years of non-point source assessment under 208 and other programs and although we do not completely understand all aspects of the problem, we feel a remedial program can now be developed. In March, 1978, the Wisconsin Legislature on recommendation of the Governor, passed a bill establishing a Non-Point Source Grant Program. This program will provide funding, on a 50% cost share basis to implement the non-point source recommendations of 208 plans. We believe this is the first program of its kind in the country, in that it's objectives are water quality protection and improvement, it provides funds for both urban and rural areas and funds will be available July 1, 1978. I would like to discuss the way in which this program will be conducted.

The legislation authorized the Department of Natural Resources (DNR) as the State Water Quality Agency to develop this grant program. The DNR is the responsible agency for 208 planning and as such is in the best position to insure consistency with water quality objectives. The program will utilize the State Board of Soil and Water Conservation Districts for coordination of cost sharing for Best Management Practices anf for technical assistance with local management agencies. The program utilizes the 208 planning process to identify problems and develop needs. In Wisconsin, these 208 plans will cover major drainage basins except for two designed areas where the planning is defined by political boundries. However, in each case the 208 plan will identify problem watershed areas and local management agencies. General needs will be identified and these areas will be prioritized within the plan. These watershed areas will then be evaluated using a statewide priority system. A minimum of 70% of the funds available for cost sharing in any given year must be used in these Priority Watersheds. The remaining funds can be used outside these priority areas, however, they must be used within an area where an approved 208 plan exists. Thus, the program is targeted at areas where nonpoint source problems have been indentified and will be used only for the implementation of Best Management Practices recommended in the 208 plan.

Once a watershed has been designated as a Priority Watershed, two additional levels of planning are initiated. A Priority Watershed Plan will be developed which will identity general problem areas and the magnitude of practices required. this information will be used by the local management agency for implementation and by the state for coordination of available funds between Priority Watersheds. Priority Watershed Plans will be the responsibility of DNR, but other agencies at the state and local level will have input.

Several techniques and tools will be used to develop the Detailed Watershed Plan. Critical areas will be identified by known water quality or as percieved by local agencies and individuals. (Fig. 1) In 1977 Soil and Water Conservation Districts were requested to coordinate local meetings to identify problem areas. The results of these meetings and other water quality and land use inventories will be used to make these initial identifications. A Priority Management Area (Fig. 2) for initial implementation will be identified. This is an area which produces the major portion of the runoff from the watershed and thus proper levels of management become more critical in this area. For example, it may be possible to control 70-90% of sediment by management of 10-20% of areas. Although techniques are not well developed for identification of Priority Management Areas, it corresponds in general to the most hydrologically active area, within the watershed, as modified by level of management, intensity of land use, soil type, topography, etc. Significant source activities will be identified within the Priority Management Areas utilizing information from Soil Surveys, The Conservation Needs Inventory (CNI). An update of the CNI was completed in 1976 involving 2% land samples of 160 acre cells. Also, streambank surveys, and potential animal waste indicators (such as the Livestock Shoreline Hazard Index, developed by DNR) will be used. This Index relates the livestock density to the stream density in a ¼ mile critical zone next to the stream.

Once the Priority Watershed Plan is developed and approved, funds will be identified and the local management agency or agencies will design and implement Best Management Practices in the areas identified in the Priority Watershed Plan. This is actually a third level of planning and will be the major responsibility of the local Management Agency. Activities other than technical assistance which will be conducted or coordinated by the Local Management Sgency will be education, cost sharing of practices and possibly enforcement of regulations.

Although the Local Management Agency will be identified in the 208 plan, the Priority Watershed Plan could refine the activities of local agencies and will provide for coordination between those units of government and agencies involved at the local level. Idealily a single agency should be identified which can administer both urban and rural portions of the program as well as any regulatory functions. In many cases this may not be possible.

In summary the Wisconsin Non-Point Source Grant Program provides for implementation of non-point source controls on a priority basis which will result in maximum water quality benefits for the money spent. We believe this will be a workable program which will meet both state and Federal objectives and goals. The program is compatable with the Rural Clean Water Program. The program provides $1,500,000.00 in FY 1979 and a projected $6,000,000.00 as a continuing biannual appropiation. The legislature has also directed that a report on the program be made prior to Janaury 1, 1982 evaluating the need for regulatory measures. We believe regulations will be required for some special land use activities, such as construction earlier than that date in order to meet program objectives. We also believe that regulation will probably be necessary in most other areas. However, intensive problem oriented voluntary programs in rural areas have never been adequately evaluated, thus a three year evaluation period was provided. The program has been designed so that minimal modification of the institutional structure will be necessary to add a regulatory mechanism.

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Fig. 1

WATER QUALITY PROBLEMS

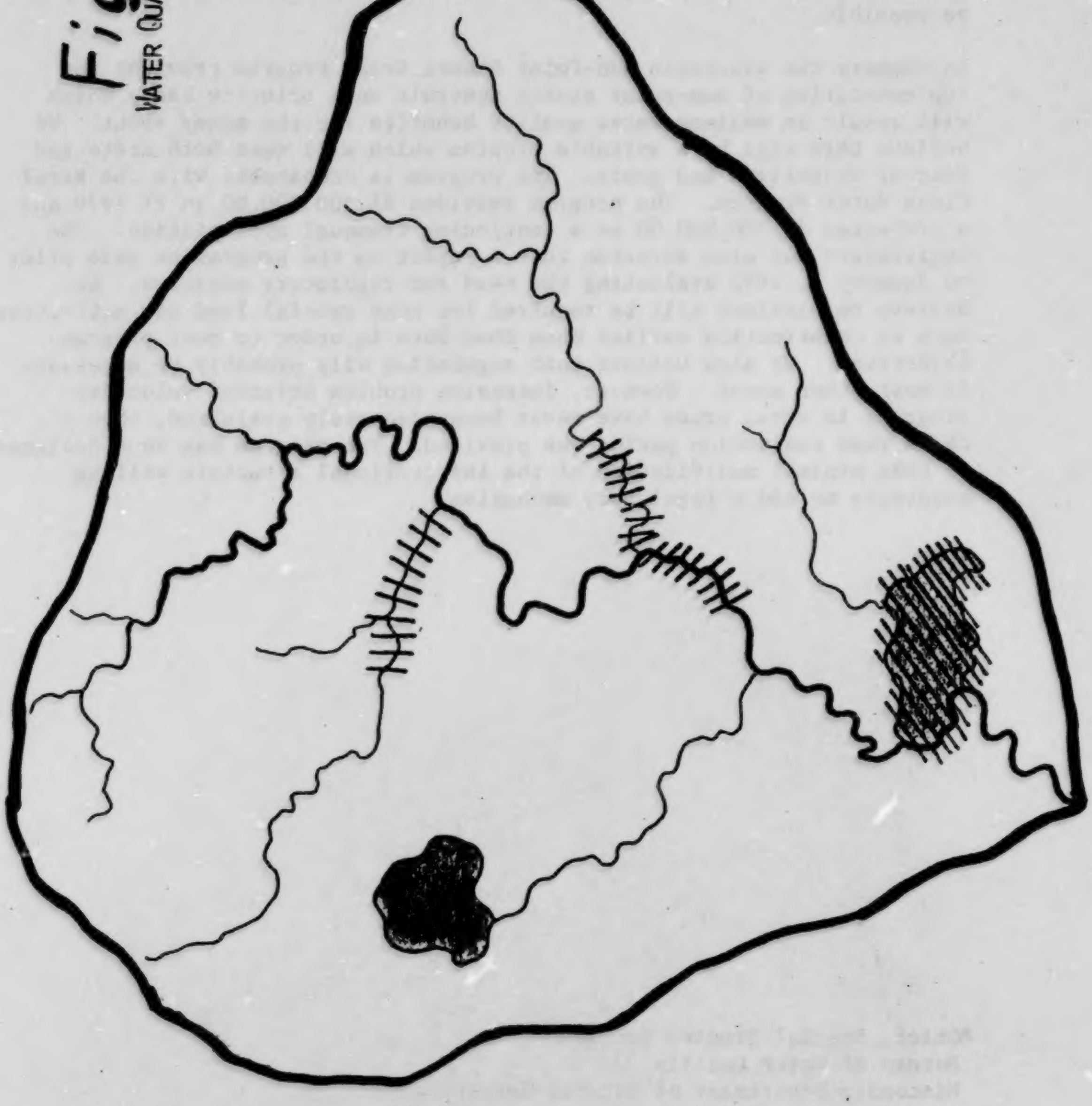
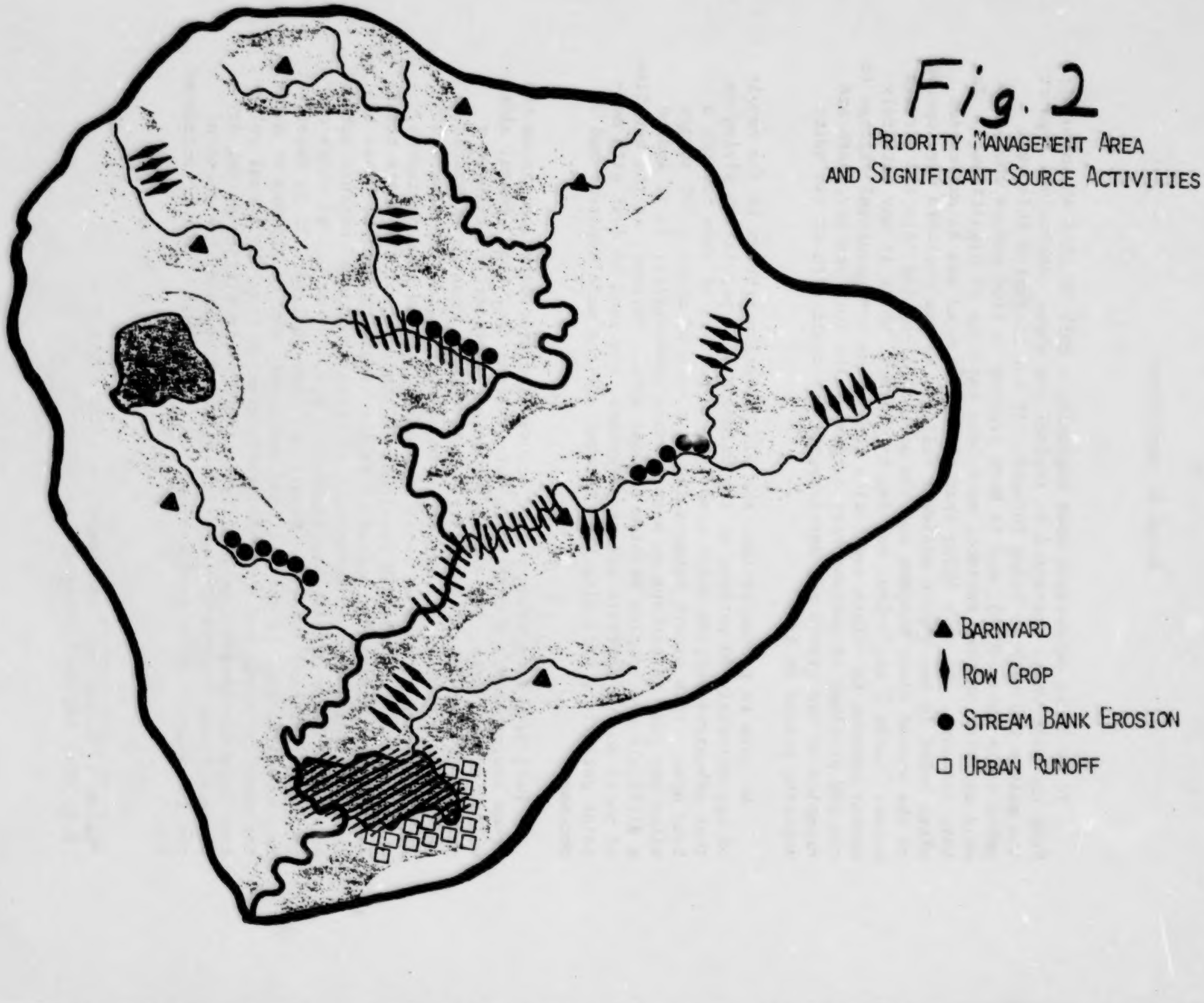


Fig. 2

PRIORITY MANAGEMENT AREA
AND SIGNIFICANT SOURCE ACTIVITIES


▲ BARNYARD
♦ ROW CROP
● STREAM BANK EROSION
□ URBAN RUNOFF

URBAN STORM WATER - A BRIEF OVERVIEW

By

Ralph V. Nordstrom*

It is often convenient when beginning a talk to cite an authority from the past whose quotation is topical and whose conclusions support the points you wish to bring forward. If one attempted this with urban storm water (USW), one is hard pressed to find anyone who has said anything on this subject, much less anything of significance. In this instance, the only thing that came to my mind was an expression often heard in the French medieval villages as the shutters were opened on the second floor windows and the pots were emptied into the streets below, "Garde l'eau"--Look out for the water! While it may outwardly appear tenuous to relate sanitation conditions in a medieval village to the USW problems of contemporary cities of the 20th century, both are examples of how growth and development were dealt with at two quite separate points in time.

We have to recognize that the USW pollution problem is the result of approximately 80 percent of the United States population living on that urbanized portion which comprises 10 percent of this country's land area. With growth progressing at a rate of about 1,500 square miles per year in perhaps as many or more communities, it is indeed a difficult and complex problem to deal with. Further, as the benefits of point source controls become effective, the need to deal with non-point pollution, including USW, becomes all the more apparent and necessary.

Pollution from urban runoff occurs when precipitation bathes the urban environment and carries pollutants from roof tops, lawns, sidewalks, parking lots, industrial complexes--whatever constitutes a surface in the urban environment. Once this process is initiated, the USW is either routed through conventional wastewater treatment facilities and given some level of cleanup, or, in some instances, when the volume of the USW overloads the capacity of the waste treatment plant, is directly passed on to the receiving waters. When the latter happens, the USW takes with it large amounts of organic debris; nutrients; heavy metals; and microorganisms, any or all of which can have a significant impact on receiving water quality. It is important to recognize that the total annual pollutant load in stormwater during the runoff periods can be considerably greater than the annual pollutant load discharged from municipal treatment facilities during dry weather flows. Obviously, even the highest levels of treatment of the dry weather flows become almost valueless when offset by untreated USW.

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From the perspective of the U.S. Environmental Protection Agency, the object of USW management is to reduce the negative impacts of runoff waters to an acceptable level with reasonable costs. Several methods may be used to achieve this objective. They are:

Source controls which limit contaminants.

1. Erosion control of construction sites.
2. Neighborhood sanitation--street sweeping, trash removal.
3. Restriction on pesticides, fertilizers, deicing compounds.

Collection Systems Controls.

1. Separation of stormwater and sanitary sewers.
2. Flushing of deposits built up in sewerlines.
3. Inflow/infiltration controls.
4. Temporarily increasing sewer line capacity and storage capability.

Storage.

Use of tunnels, parking lots, rooftops to create surface and subsurface impoundments to provide temporary storage of stormwater.

Combinations of the above.

The application of these control methods is often restricted by the suitability of the control to the urban situation it is being used in. In an existing development, street cleaning and other contaminant-limiting methods may be the only practical manner of dealing with the problem. However, in newly developing areas, source controls; collection system controls; and possibly various storage devices could be used to attenuate the rate of runoff. Consequently, newly developing areas may provide the greatest flexibility in USW control application. Further, they should also provide opportunities to maximize a preventive approach which stresses utilization of the existing natural features to reduce stormwater flow. Often it is possible to maintain and provide sufficient open space, as parks; playgrounds; greenbelts, to allow recharge of ground waters and to maintain surface catchment ponds for permanent or temporary storage. The recharge of ground waters would not only reduce volume of flow, but often reduce the capital costs required to contain these flows. In short, by minimizing the impacts of development, it is possible to preserve some of the watersheds existing runoff characteristics. This may seem a simple straightforward concept, but many communities fail to provide this type of guidance to development.

Planning for spatial allocation of development can reduce runoff generation as can public acquisition of open space and preservation of permeable areas.

Regulation of certain types of land uses through performance standards can also reduce the generation and accumulation of runoff.

Runoff detention in impervious areas reduces the peak flow and extends the period of treatment. Runoff detention in previous sites allows ground water recharge through percolation and reduction of total overland flow. Through the above devices it is possible to develop smaller treatment facilities and lower operating and maintenance costs.

A preventive approach with USW requires that urbanizing areas not necessarily accept whatever development comes along and simply collect the runoff as if it were raw sewage. In turn they should directly regulate activities or insure that the development that does occur is accompanied by safeguards that will minimize the generation and accumulation of runoff waters.

BEST MANAGEMENT PRACTICES FOR URBAN DRAINAGE

ROCHESTER, NEW YORK

by

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The recently issued Fifth Annual IJC Report on Great Lakes Water Quality (1) has acknowledged the impact of urban runoff in the Great Lakes Basin as evidenced in the following excerpts:

> "The Commission believes that combined sewer overflows and stormwater flows from urban areas are reaching serious proportions and contribute significant amounts of a wide range of harmful substances in the Great Lakes."
>
> "The Commission is aware that substantial funds and manpower are being directed to finding solutions to this complex problem in both countries."
>
> "The Commission considers it a matter of high priority that these efforts be accelerated."

Urban runoff is composed of two major components, stormwater and combined sewer overflow. Stormwater discharges consist of runoff from impervious areas which has been contaminated by pollutants accumulated on the various surfaces due to chemical spillage, air pollution, atmospheric washout, the application of highway deicing agents, and the accumulation of surface debris and liter.

The pollutant loading from urban runoff is as variable as the land use activity, annual rainfall and surface management practices employed for each drainage area. In general urban stormwater discharges are characterized by significant and variable concentrations of suspended solids, nutrients, heavy metals, biochemical oxygen demand, viruses, indicator organisms and toxicants. Combined sewer overflows typically have similar characteristics as stormwater discharges except for significant increased concentrations of viruses and indicator organisms.

The concentration of biochemical oxygen demand substances characteristic of combined sewer overflows can be significantly greater than that exhibited by stormwater, particularly for those systems which exhibit a strong first flush effect. A range in urban runoff constituent concentrations measured as part of the IJC PLUARG Pilot Watershed Studies is presented in Table 1.

Table 1. Urban Runoff Unit Area Load Analysis

Constituent	Load (kg/ha/yr)
Suspended Solids	200 - 4800
Total Phosphorus	0.3 - 4.8
Total Nitrogen	6.2 - 18
Lead	0.14- 0.5
Copper	0.02-0.21
Zinc	0.3 -1.0

a. Source: IJC PLUARG Pilot Watershed Studies

URBAN RUNOFF TOXICANTS

To date investigators have to a large degree neglected the toxicants contributed to receiving waters by urban runoff. In the course of conducting the Rochester, New York Combined Sewer Overflow Abatement R & D Program (EPA Grant No. Y005141) O'Brien & Gere in conjunction with the Monroe County Division of Pure Waters has evaluated the concentrations of a number of toxicants within combined sewer overflows. Figures 1 and 2 present the annual variation of mercury and chlorinated organic concentrations measured on composite wastewater samples collected throughout the year. The average measured mercury concentration measured during the 1975 monitoring year was 18.1 μg/l. A review of the data indicates that the annual contribution of mercury on an areal basis is 0.034 kg/ha (0.03 pounds/acre).

The chlorinated organic concentrations averaged 6.6 μg/l for the 1975 monitoring year with peak concentrations of 32 μg/l. This represents an annual contribution of chlorinated organics on an areal basis of 0.011 kg/ha (0.01 pounds/acre).

The test catch basin study clearly indicates that toxicants discharged in urban runoff can be very significant and in many cases exceed the discharge of these same toxicants from point sources in urban areas. Through more comprehensive evaluations it may well be established that the contribution of toxicants from urban areas to tributary receiving waters may be more significant that the load of oxygen demanding constituents.

Figure 1. Annual Variation In Combined Sewer Overflow Mercury Concentrations 1975 Data

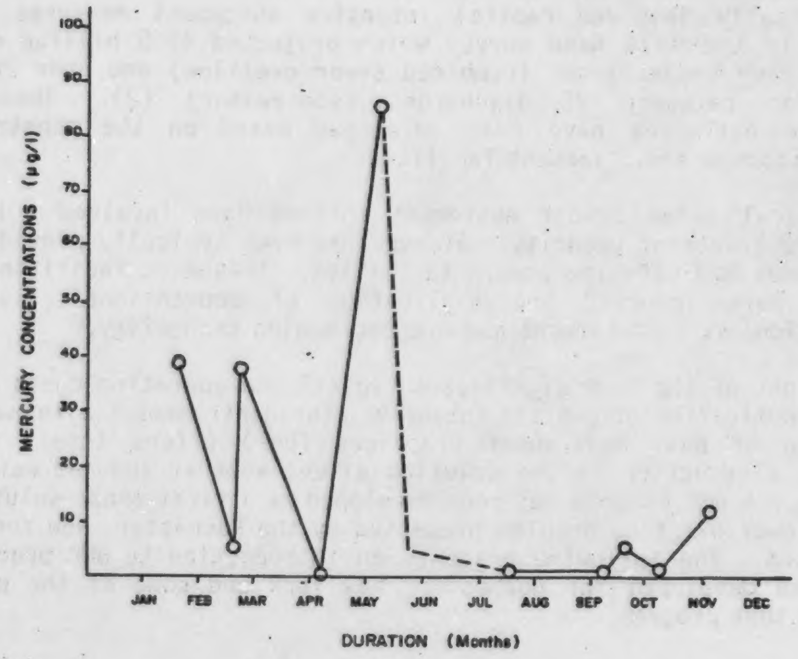
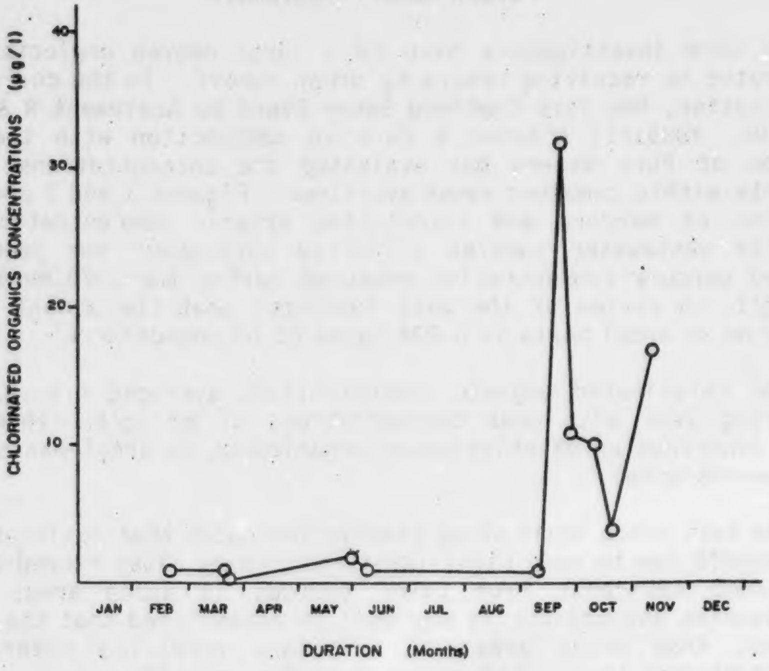


Figure 2. Annual Variation in Combined Sewer Overflow Chlorinated Organics Concentrations 1975 Data



ABATEMENT ALTERNATIVES

The abatement of combined sewer overflow and urban stormwater discharges has classically involved capital intensive abatement measures. This is reflected in the 1974 Need Survey which projected 43.5 billion dollars to abate category V discharges (combined sewer overflow) and over 200 billion dollars for category VI discharges (stormwater) (2). These capital expenditure estimates have been developed based on the construction of extensive storage and treatment facilities.

Classical urban runoff abatement options have involved a balance of storage and treatment capacity. Storage has been typically provided via in-system tunnel and off-line cavern facilities. Treatment facilities have for the most part involved the application of conventional flocculation/sedimentation, swirl treatment and microscreening technology.

In light of the very significant capital and operating costs associated with the application of capital intensive storage/treatment alternatives, the application of Best Management Practices (BMP) offers itself as a very attractive alternative to the solution of wet weather induced water quality impairment. A BMP program has been developed as a first phase solution to the combined sewer overflow problem presented by the Rochester, New York combined sewer system. The following presents an introduction to BMP practices, the BMP program developed for Rochester, New York and some of the preliminary results of that program.

BEST MANAGEMENT PRACTICES

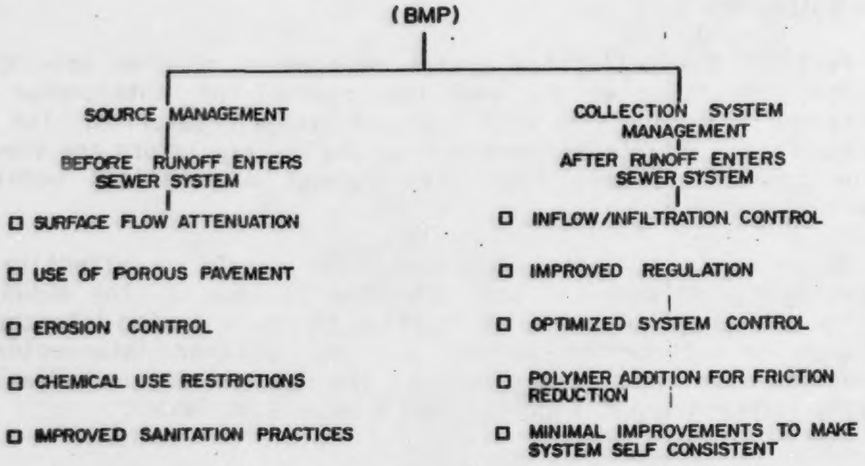
A rational and cost/effective solution to the abatement of both stormwater and combined sewer overflow involves the application of the concept of Best Management Practices (BMP) (3). A BMP program focuses on the source and collection system management. A breakdown of the various elements of a BMP program is shown in Figure 3.

Source management involves the application of measures to reduce or prevent pollutant loading before runoff enters the conveyance system. Typical source management abatement measures include the application of surface flow attenuation, use of porous pavement, erosion control, restrictions on chemical usage, land use planning, and improved sanitation practices including trash removal and street cleaning.

Collection system management involves the application of all abatement alternatives which pertain to the collection system. Collection system management alternatives therefore involve all those abatement alternatives applicable after the runoff enters the collection system. Typical solutions fall into two basic categories, structural intensive and minimal structural.

The collection system management alternatives which are of interest in a BMP program involve those requiring the expenditure of minimal resources. Relevant collection system management practices involve inflow/infiltration control, improved system regulation, optimized system control, polymer addition for friction reduction, and minimal improvements to make the collection system self consistent (elimination of conveyance system throttling constraints).

Figure 3. Combined Sewer Overflow and Stormwater Best Management Practices


(BMP)
SOURCE MANAGEMENT
BEFORE RUNOFF ENTERS SEWER SYSTEM
☐ SURFACE FLOW ATTENUATION
☐ USE OF POROUS PAVEMENT
☐ EROSION CONTROL
☐ CHEMICAL USE RESTRICTIONS
☐ IMPROVED SANITATION PRACTICES
COLLECTION SYSTEM MANAGEMENT
AFTER RUNOFF ENTERS SEWER SYSTEM
☐ INFLOW/INFILTRATION CONTROL
☐ IMPROVED REGULATION
☐ OPTIMIZED SYSTEM CONTROL
☐ POLYMER ADDITION FOR FRICTION REDUCTION
☐ MINIMAL IMPROVEMENTS TO MAKE SYSTEM SELF CONSISTENT

BEST MANAGEMENT PRACTICES IMPLEMENTATION PROGRAM, ROCHESTER, NEW YORK

A Best Management Practices Implementation Program has been developed for the Rochester, New York Pure Waters District for the abatement of combined sewer overflow discharges to the Genesee River, Irondequoit Bay, and the Rochester Embayment of Lake Ontario (4). This program is broken down into fourteen major elements which are presented as follows:

1. Preparation of Detailed Work Plan
2. Second Generation Monitoring System Evaluation
3. Interceptor Improvements-Assessment of Cost Benefit and Development of Basis of Design
4. Combined Sewer Overflow Regulation Modifications
5. Selective Control Adjustments of High-Impacting Overflows
6. Pollutant Source Control Measures
7. Additional Control Structure Evaluations
8. Control System and Operating Logic
9. CSO Receiving Water Impact Studies
10. Receiving Water Benthic Demand Studies
11. Evaluation of Developmental Sewer Flow Monitoring Equipment
12. Hydro-Brake and In-Line
13. Catchbasin Evaluations
14. Program Evaluation and Final Report

The basic approach being employed in the Rochester BMP program involves the assessment of baseline conditions utilizing an upgraded combined sewer overflow monitoring system, the implementation of each BMP program element, and the evaluation of program effectiveness through the collection of process efficiency data. The overall program effectiveness will be assessed through the post implementation evaluation of CSO monitoring data as well as receiving water response. The program is approximately 2-1/2 years in duration and is being conducted in very close coordination with existing and anticipated EPA Construction Grant activities.

PRELIMINARY FINDINGS BEST MANAGEMENT PRACTICES IMPLEMENTATION PROGRAM, ROCHESTER, NEW YORK

Part of the collection system management program developed for the Rochester BMP program include the removal of interceptor throttling constraints in conjunction with improved system regulation. The location of the significant interceptor bottlenecks and key regulators are shown in Figure 3. The constraints were identified through mathematical modeling of the collection system.

In order to evaluate where resources should be effectively applied, network hydraulic modeling was conducted to identify the annual volume of overflow and annual duration of overflow for the existing interceptor system, the upgraded interceptor system, and the upgraded interceptor system in conjunction with improved regulation. The results of this hydraulic modeling activity is presented as Figures 4 and 5 as well as Table 2.

Table 2. Overflow Frequency and Volume Model Output

Condition	Volume - MG Min. Yr.	Volume - MG Ave. Yr.	Volume - MG Max. Yr.	Duration - Hrs. Min. Yr.	Duration - Hrs. Ave. Yr.	Duration - Hrs. Max. Yr.
Existing	1005	1574	1903	362	425	572
Removal of Flow Restrictions from M.S.D.S.	1005	1574	1903	362	25	572
Modified Regulators	858	1432	1695	255	297	414
Removal of M.S.D.S. Restrictions and Modified Regulators	556	1060	1217	83	119	147

The exhibits indicate the combined sewer overflow volumes and frequency based on annual projections for the minimum, maximum and average rainfall years of record under three sets of system conditions.

1. Existing M.S.D.S. interceptor
2. Removal of restrictions within the M.S.D.S.
3. Existing M.S.D.S. with modified regulators

Figure 4. Rochester BMP Program Interceptor Modification

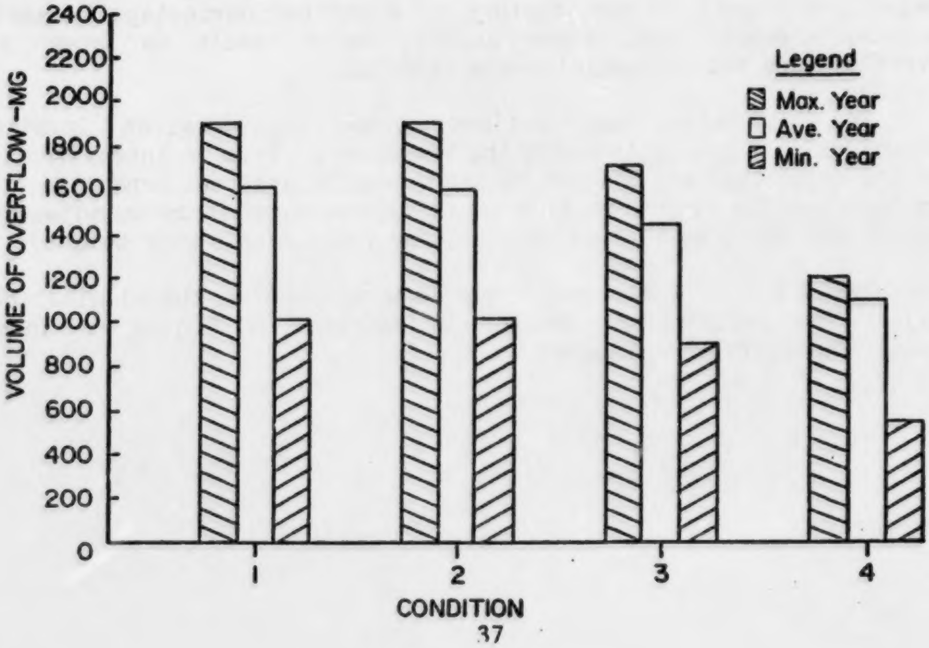
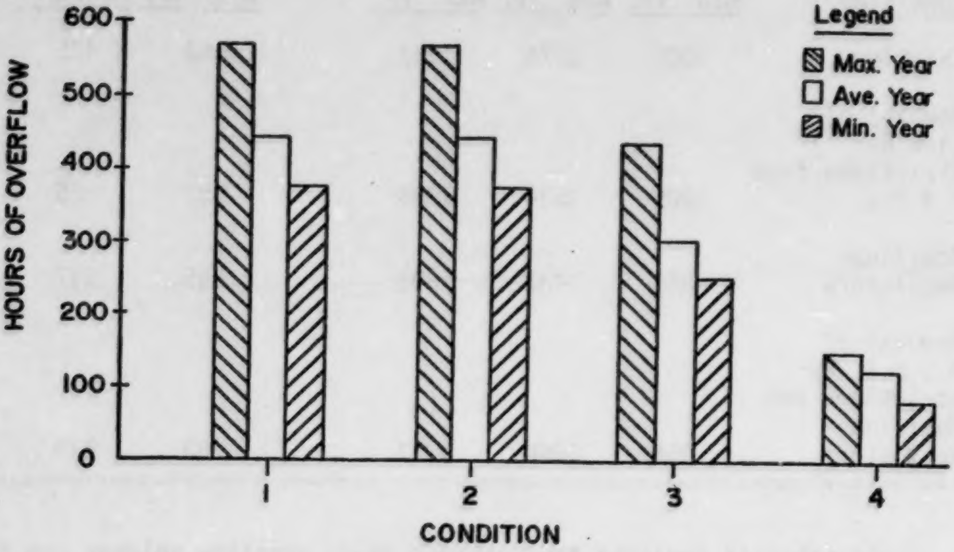


Figure 5. Rochester BMP Program Interceptor Modification



Considering the average year modifications to the regulators would result in a 9% decrease in CSO volume and a 30% decrease in the number of hours of overflow; whereas, total system improvements involving the M.S.D.S. and the regulators would result in a 33% decrease in overflow volume and a 72% decrease in hours of overflow. It can be seen that improvements to the system result in a greater percentage decrease in hours of overflow than in volume of CSO. This is due to the fact that improvements to the M.S.D.S. and/or regulators result in the capture of a greater percentage of smaller storm events, whereas, the larger events, which result in larger volumes of overflow, are not as significantly affected.

The regulator modifications under consideration involve minimal structural changes to the existing structures. From an intensive field survey of the regulators and the subsequent hydraulic analyses conducted, the ability to increase the regulated flow would include such items as adjusting a float level, enlarging an orifice opening, and increasing a weir height.

The M.S.D.S. interceptor improvements involve the elimination of three major flow restrictions which are indicated on Figure 3. These lengths requiring improvement include:

1. The section of interceptor from the Carthage Drive junction chamber to the intersection of Norton Street and St. Paul Boulevard, where the East Side Trunk Sewer (E.S.T.S.) enters the M.S.D.S.

2. The interceptor siphons under the Genesee River from the Cliff Street screenhouse to the junction chamber at Carthage Drive, and

3. The siphons under the Genesee River from the Glenwood Screenhouse to the junction chamber at Carthage Drive.

The presented regulator and interceptor modifications are only a portion of the system management portion of the BMP program. The effectiveness of these modifications and their associated low capital investment (~$8,000,000) indicate the effectiveness of the BMP methodology in handling urban runoff problems.

ADVANTAGES OF BEST MANAGEMENT PRACTICE PROGRAM

The application of a BMP program is anticipated to offer a number of advantages over the application of conventional capital intensive technology to solve urban runoff pollution problems. These advantages are outlined as follows:

- Solutions are more quickly facilitated
- Less capital intensive
- Addresses the problem at the source
- Maximizes the use of existing facilities
- Minimizes the development of secondary problems

A BMP based solution to stormwater and combined sewer overflow problems may only provide a partial solution. More capital intensive classical storage and treatment options may be required to meet water quality objectives. However, BMP based solutions may offer very cost/ effective interim measures which serve as a good first step. Results from the BMP Implementation Program can be used to better define the reduced overflow problem and thus possibly scale down the more structurally intensive alternatives.

In light of the extensive capital costs associated with classical solutions, BMP programs offer a very viable alternative to the abatement of urban stormwater and combined sewer overflow problems. It is the hope of all those associated with the Rochester, New York program; that the demonstration and evaluation of BMP abatement measures will show these solutions to be extremely cost/effective and practical.

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1. "Fifth Annual Report-Great Lakes Water Quality", International Joint Commission, Windsor, Ontario, Canada (1976).

2. "1974 Survey of Needs for Municipal Treatment Facilities" USEPA Office of Water and Hazardous Materials, Washington, D.C.

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4. "Best Management Practices Implementation Program" Federal Great Lakes Initiative Grant No. G0053341, Monroe County, Division of Pure Waters, Rochester, New York, November (1978), Detailed Work Plan, January (1978).

INSTITUTIONAL CONSIDERATIONS
URBAN NONPOINT SOURCE POLLUTION CONTROL

by

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Paper not available at the time of printing. Paper can be obtained by requesting it from the author or Great Lakes National Program Office, 230 South Dearborn Street, Chicago, Illinois 60604.

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THE NEED FOR SEDIMENT REGULATION:
THE WASHINGTON COUNTY EXAMPLE

by

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The Washington County Project is funded under Section 108 of Public Law 92-500 and is attempting to design a mechanism--or mechanisms--to control sediment problems in Washington County in southeastern Wisconsin. The grant for the project was awarded to the State Board of Soil and Water Conservation Districts (BSWCD), and through the State Board linkages were established between the cooperating project agencies and the local Soil and Water Conservation District.

A brief word about Soil and Water Conservation Districts (SWCDs) in Wisconsin as the arrangements there are somewhat unique. Chapter 92 of the Wisconsin Statutes creates SWCDs and states that the SWCD supervisors shall be those persons who serve on the Agriculture and Extension Education Committee of the County Board which is a standing Committee of that Board created under Chapter 59 of the Wisconsin Statutes.

This relationship gives the SWCDs some natural ties to county government. It means that in Wisconsin, Soil and Water Conservation Districts are coterminous with counties. On the other hand, it does mean that Soil and Water Conservation District Supervisors do not stand election for their jobs but rather that they are handed the responsibilities if they serve on the Agriculture and Extension Education Committee.

It should be noted here that recent amendments to Chapter 92 provide for the appointment of two additional persons to the committee, a feature designed primarily to insure representation from either urban areas or the education community if such representation is appropriate or necessary.

Washington County was selected for the project because it is a county in transition. Basically a rural county with a strong rural tradition, it now finds itself under tremendous pressure from the Milwaukee Metropolitan Area and Milwaukee County with which it shares a common border. All the classic problems are there: sewer extensions, septic tanks, farm lands being held for development, prime ag lands being converted to houses, city folks scattering around the countryside wanting to live in the country yet demanding urban services and the list goes on.

It should be obvious, however, that the county serves well as a location for the project. It has provided an on-the-ground opportunity to monitor selected land uses to determine sediment and nutrient yields and then to install remedial measures and to assess their effectiveness in reducing pollutant outflow. By working with governmental bodies in both incorporated and unincorporated areas, the project has had the opportunity to test ideas and strategies on people responsible for program development and implementation and to work with county officials and citizens alike to develop mechanisms for sediment control. It has provided researchers with valuable data to assess the economic impacts of varying levels of sediment control on individual farmers, to evaluate the problems of sediment losses from land in transition between farming and housing as well as insights into a wide variety of other problems.

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It probably should be noted here that we may have found in Washington County the ultimate accomodation between urban and rural interests. There is now pending in Germantown--a rapidly developing area in the southeastern corner of the county--an application for a permit for the construction of a condominium for horses.

Finally, Washington County has served as an important testing ground for public information and education strategies. Public understanding and awareness of nonpoint problems and solutions is a key ingredient of any NPS control strategy whether voluntary or regulatory.

The Washington County Project devoted a good deal of time and effort to reviewing the statuatory aspect of sediment control. Initially, existing authorities available to local jurisdictions which might be utilized for sediment control were identified and examined and then the decision was made to develop a two phase approach with Phase I including those pollution control initiatives which a local government might take under existing authority and with Phase II envisioning a more extensive approach with the distinct possibility of new state enabling legislation.

By way of background, it should be pointed out that water resources management for water quality has been and continues to be the prime responsibility of the United States Government and the several states. On the other hand, land use management issues have been handled for the most part at the local level; but the problem of nonpoint source pollution from land-based activities demands that the water quality programs and the land use programs be linked in an effective and manageable way. Therefore, our objective in the Washington County Project has been to develop programs for sediment control that would be implemented locally in response to and consistent with federal and state water quality goals and requirements.

We have concentrated initially on the development of tools which can be used by the local authorities in the development of a strong institutional structure to manage the sediment control programs. This includes both voluntary and regulatory components. The two major regulatory components that we have worked with are related to erosion control under a land subdivision ordinance and an agricultural soil conservation ordinance. The land subdivison ordinance, under the general existing authority of Chapter 236 of the Wisconsin Statutes, is at the present time being incorporated into the Washington County subdivision ordinance.

It provides in general that the Soil and Water Conservation District may pose objections to preliminary plats if it considers that land is unsuitable for subdivision and construction, or if adequate provisions for stormwater management and soil conservation have not been made. This kind of amendment to the existing county ordinance has been recommended for County Board approval both by the Washington County Park and Planning Commission, which handles zoning in the county, and by the Washington County Soil and Water Conservation District. Several municipalities are also proceeding under their home rule authorities with similar amendments to their subdivision control ordinances.

The rural ordinance has been drafted pursuant to the Chapter 92 of the Wisconsin Statutes, which delegates to the Soil and Water Conservation District the authority to formulate and enforce land use regulations provided that these regulations are approved by the County Board and by the voters affected by the regulations through referendum in their particular area. To date, this authority has been used effectively in only one town in one county of the state--a town in Vernon County. The proposed rural ordinance has been drafted in cooperation with the District, but as yet no firm plans have been made to submit it for referendum; but I must say in all candor, given the reluctance of EPA and the State of Wisconsin to pursue a regulatory program at this juncture, in my judgment the Washington County authorities are unlikely "to lead a charge" for enactment of a regulatory measure in their county at this stage of the game. But with respect to what it would do if it were enacted, the ordinance as now developed, would require that farming units larger than 10 acres meet certain limited soil loss requirements as calculated by the Universal Soil Loss Equation. Soil losses could not exceed on the average three tons per acre per year for any farming unit, or more than nine tons per acre per year for any one acre parcel, the "hot spots" within a farming unit.

Any farm owner or operator who had a District approved soil and water conservation farm plan would be presumed to be in compliance; and capital expenditures could not be required for compliance unless cost sharing monies were available.

It has been estimated by our working group the soil losses on about 20% of the cropland in Washington County exceed three tons per acre per year; average soil loss for cropland there is about 2.4 tons. Under the proposed ordinance, it is anticipated that between 100 and 150 farms--of the nearly 1400 farms in the county--would be required to reduce soil losses by 50%. This reduction would result in an overall 35% reduction in sediment losses from cropland. Our work suggests that most of the non-complying farms could comply by adopting modest changes in crop rotations and tillage practices.

Furthermore, our economic analysis indicates that the typical farmer would not suffer a significant loss of income if he is obliged to comply with such an ordinance. We consider this kind of modest regulatory approach administered at the local level to be a vital element in ensuring that no farmer is contributing an excessive amount of sediment to the lakes and streams, although, and this is the conventional wisdom of the day, a wholly voluntary approach to the problem supported with substantial cost sharing funds might be modestly effective. But we of the project believe there is little evidence to suggest that enough remedial change would be accomplished unless a reasonable regulatory program is in fact employed! However, it is not likely that there will be an immediate federal or state requirement for the regulation of agricultural practices.

There is widespread belief that voluntary programs should be tried before any type of regulation is imposed; and one can't quarrel with the general principal of that, except as I suggested, we have grave doubts as to whether or not a wholly voluntary program will, in fact, meet the problem. It is also quite certain that if these voluntary measures fail to meet the national water quality objectives, then some form of regulation will become mandatory. Mr. Douglas Costle, the Administrator of EPA, has observed in a recent speech to the Conference of Soil and Water Conservation Districts: "You and we need to encourage achieving the goals of the Act by voluntary means. If and when these means do not succeed, we need to ensure that there is an effective reasonable regulatory backup to get the job done in a timely fashion."

As part of the 208 planning process, the Soil and Water Conservation Districts in Wisconsin, under the auspices of the State BSWCD and Department of Natural Resources (DNR), inventoried approximately 2% of the land in each county. Specific management practice information was collected. For croplands, this included information on slope, soil type, slope length, and data on rotations, plowing methods, and the utilization of conservation practices.

From this data, we were able to estimate average annual soil loss rates for each field surveyed via the Universal Soil Loss Equation. The results obtained from this evaluation can only be viewed as approximations due to the small proportion of land sampled. Of the 120,000 acres of harvested croplands in Washington County, 2900 acres were analyzed in the 36 quarter-sections sampled. This does provide, however, the best information available on how lands with high erosion potential are being managed.

The results for 6 counties in southeastern Wisconsin are shown in Figure 1. The critical finding is that to a large extent in all counties analyzed, a relatively small acreage accounts for a fairly large proportion of the total soil loss from surveyed croplands. About 50% of the soil loss comes from between 10-20% of the land.

We have looked at the results from Washington County in more detail in order to characterize more precisely the nature of the major contributing areas. The results are not surprising. The 21% of the cropland that is on slopes greater than 6% contributes 57% of the total cropland soil loss. Nearly 70% of these steep lands are plowed up and down slope. Fields on slopes greater than 12% included only 6% of the cropland acreage but account for 31% of the total soil losses. Of this land, the 20% in continuous corn accounts for 70% of its losses. In fact, one 20 acre field of the 146 surveyed accounted for nearly one-fifth of the total cropland soil loss, with an average soil loss rate of 62 tons per acre per year. This evidence suggests rather strongly that significant reductions in sediment losses from croplands can be achieved by focusing our efforts on relatively small areas. Such an approach would seem to make infinite good sense from almost any way you look at it.

Why should we regulate sediment control seems to be the next question. There appear to be several compelling reasons. First, and perhaps foremost, it should be apparent that voluntary programs have not been particularly successful. Nationwide participation in federal cost sharing programs hovers around 30% after 30 plus years of experience.

In recent demonstration projects like the Allen Co. Project in Indiana and the White Clay Lake Project in Wisconsin, full cooperation has not

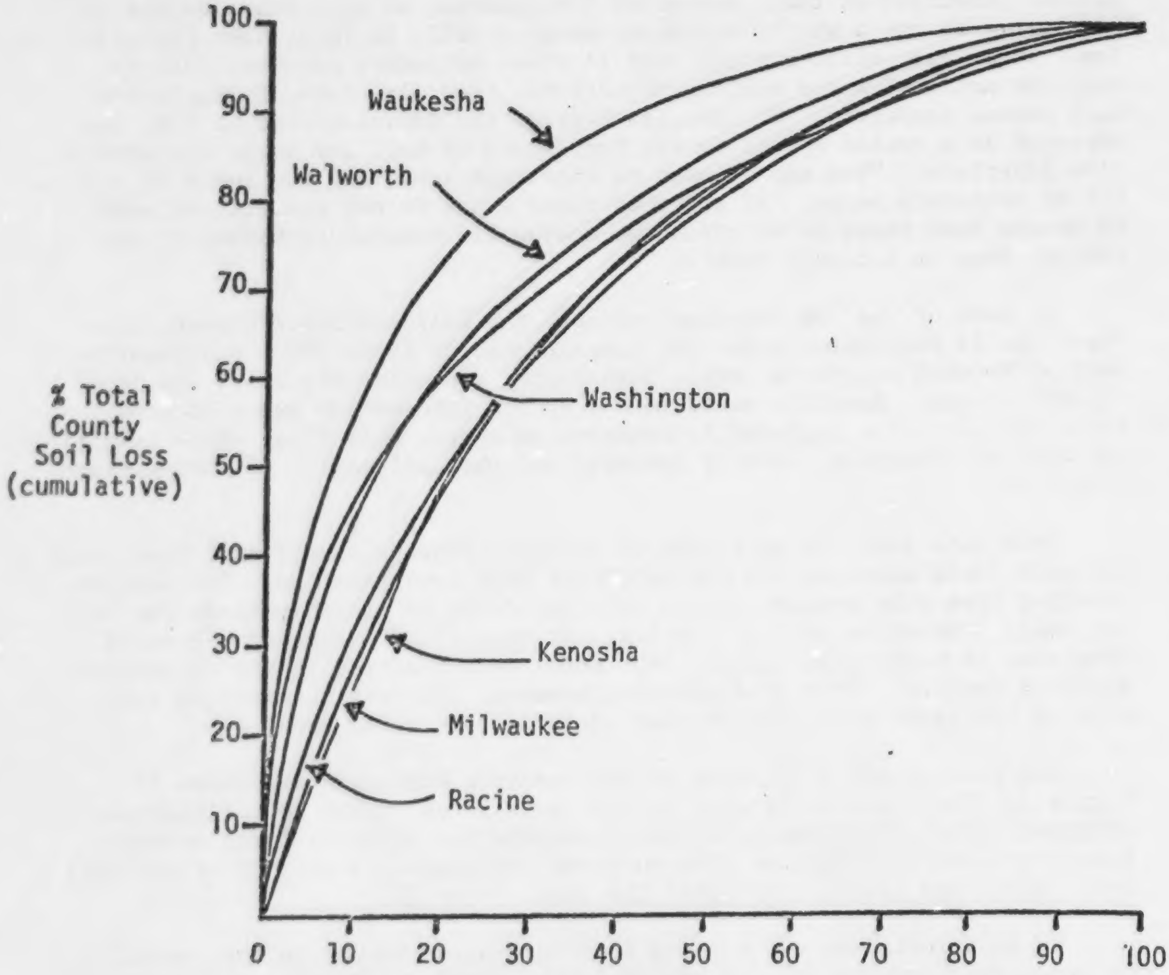

Figure 1. Cumulative Distribution of Cropland Soil Loss in Southeastern Wisconsin Counties*

*Based on a 2% sample of land in each county been achieved and problems have not been solved. In the latter case, for example, much can be made of the fact that of all the farms in the watershed having livestock, all but three installed barnyard and waste handling facilities with project funds. This is about 85% cooperation; it should be noted that among the noncooperators, one farmer waters his hogs in the lake itself and another regularly spreads manure in the winter time along a perennially running stream. Quite clearly, cooperation of 75 or 85% of the farmers in a given watershed does not guarantee solution of the nonpoint problem.

Further, it is our judgment that a modest regulatory program like the one designed by the Washington County Project would serve to focus institutions on the problem. Our proposed ordinance makes the cropland problem into a critical areas problem which, once identified, becomes the focal point for local, state and federal agency efforts. Wall to wall conservation, though desirable, is not feasible given our current constraints on technical manpower and the time constraints imposed by the Congress in PL 92-500 and PL 95-217.

Nationwide, the nonpoint problem is assuming an ever greater percentage of our total water quality problems. Current estimates are that the problem is now about 50% point and 50% nonpoint. Yet, the President's budget for FY 1979 would appropriate $4.5 billion for point source control programs and zero dollars for nonpoint programs unless the $90 million earmarked for Agricultural Conservation Programs is considered to be for nonpoint control. Hopefully, the Congress will move to rectify this imbalance, but even so, the disparity in support for the two efforts will remain great.

The significant fact here is that as the point source problem moves toward solution, nonpoint programs will receive more and more attention and will probably require more and more public monies. These monies simply are not going to be made available unless reasonable constraints are placed upon their use.

In summary then, it does not appear to be a question of regulation but rather a question of how to design a regulatory program which will help us to solve the problem, which will provide adequate controls on the expenditure of public funds and which will not impose undue economic constraints on those who are affected. Such a program is within our grasp and we are doing ourselves and the public a great disservice by suggesting that we might be able to handle the problem in some other way.

INSTITUTIONAL NEEDS FOR EFFECTIVE NONPOINT SOURCE POLLUTION CONTROL PROGRAMS

by

Jim Arts and Steve Berkowitz*

In this paper we discuss two major topics:
(1) What does our experience in Washington County tell us about how well existing programs have worked to reduce soil erosion and sedimentation?
(2) What are the institutional changes needed to improve implementation of erosion control and water quality programs?

There is no question that the effort to reduce nonpoint source pollution (NPS) will be intensive and complex. In Wisconsin new cost-sharing programs are coming on line, and the 208 process will soon be reaching the crucial implementation stage. Serious consideration must be given to determining the best institutional methods for implementing new and continuing programs.

We should point out, incidentally, that the Washington County Project has by design focused on sediment, rather than upon the entire spectrum of NPS problems; but we believe that, in general, our conclusions regarding the control of sediment are applicable to other forms of NPS as well.

The success of the programs designed to control NPS pollution hinge on the degree to which existing action agencies can be directed toward solving specific problems. The most important ongoing programs are administered at the local level by the county Soil and Water Conservation Districts (SWCD), federal Soil Conservation Service (SCS), and federal Agricultural Stabilization and Conservation Service (ASCS). To highlight the institutional changes which may be necessary to enable these agencies to effectively take on an expanded role in water quality improvement, we have made a careful evaluation of these programs' performance within the context of their existing mandate which is directed toward soil erosion control. While generalizations about these programs cannot be justified conclusively on the basis of just one case study, we feel the Washington County experience is representative and underscores some of the critical institutional questions which must be addressed by those involved in the development of NPS control programs.

Figure 1 shows the average annual practice accomplishments by SWCD/SCS technical staff from 1973 to 1976 in Washington County (this includes nearly all ASCS-cost-shared projects). About 1000 acres per year are being protected with major erosion control practices and another 2000 acres per year have conservation cropping systems developed for them. While these accomplishments are substantial, two questions arise immediately: (1) is this enough? and (2) is the current effort being directed to where the

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Practice	Acres Affected (Average Annual)*	
Major Erosion Control	976	
Stripcropping		226
Diversions		49
Grass-Waterways		237
Minimum Tillage		288
Contouring		138
Critical Area Planting		9
Conservation Cropping Systems	1949	
Vegetative Cover Practices	210	
Woodland Practices	179	
Wildlife Practices	456	
Drainage Practices	237	
Total Accomplishments	4007	

*Derived from SCS "F-Reports" for 1973-74, 1974-75, and 1975-76, and ASCS Annual Reports.

Figure 1. Practice Accomplishments of the Washington County SWCD, SCS and ASCS, 1973 to 1976.

needs are greatest? The answers to both of these critical questions can only be roughly given, due to the limited amount of information available. From our analysis of a 2 percent survey of land in the county in 1976, we estimate that approximately 20 percent of the actively farmed land in Washington County is losing more than 3 tons/acre/year or about 20,000 to 25,000 acres. This suggests that the current accomplishment levels are not enough to meet accepted erosion control standards, particularly when one considers that there is currently no means of assuring that practices installed are maintained. We also have found that a lesser amount of land contributes the greater proportion of cropland soil loss, emphasizing the need for programs to be focused on those lands with the greatest needs.

We have utilized data collected by the Southeastern Wisconsin Regional Planning Commission to determine how well practice accomplishments in the past have been directed toward those areas most needing treatment. Our findings are disturbing, as shown in Figure 2. The distribution of ten years of SWCD/SCS and ASCS major erosion control practice accomplishments among lands of varying slopes were evaluated. While this analysis can only be viewed as a rough one, there appears to be little correlation between practice accomplishments and erosion control needs. The accomplishment distribution follows the area distribution closely, suggesting a fairly even spread of projects over the land. This brings out the primary institutional dilemma--how can programs be better directed to areas with the greatest needs.

We have also studied the past allocation of technical assistance staff time and conservation cost-sharing expenditures in Washington County. Our findings are presented in Figure 3. Only 15 percent of the technical assistance effort and 32 percent of the cost-sharing expenditures, on the average in recent years, has gone into implementing practices which primarily reduce soil loss. The ability of both programs to assist farmers with high priority needs has been compromised in part by substantial commitments to more production oriented practices.

The traditional conservation planning process needs to be evaluated. The large proportion of technical staff time that currently goes into planning (36 percent) is particularly questionable when viewed in the context of what is getting accomplished. As of July 1976, over 100,000 acres of the land in farms in Washington County (65 percent of the county total) still were not covered by a farm conservation plan. The current rate of planning is around 3000 acres planned per year. Consideration should be given to developing a less comprehensive single-problem oriented conservation plan.

This information suggests that a redirection is needed in Washington County to focus more of our limited personnel and financial resources on the problem areas. The next question is to consider how this can be done.

First of all, we believe it is necessary to define an institutional focal point for local planning and implementation. In 208 terms, who is going to be the local management agency?

After considering various alternatives, we believe the that Soil and Water Conservation District is the best alternative. In fact, if the SWCD did not exist, it may have been necessary to create it. We note that the SWCD has had a long history of directing programs related to soil erosion,

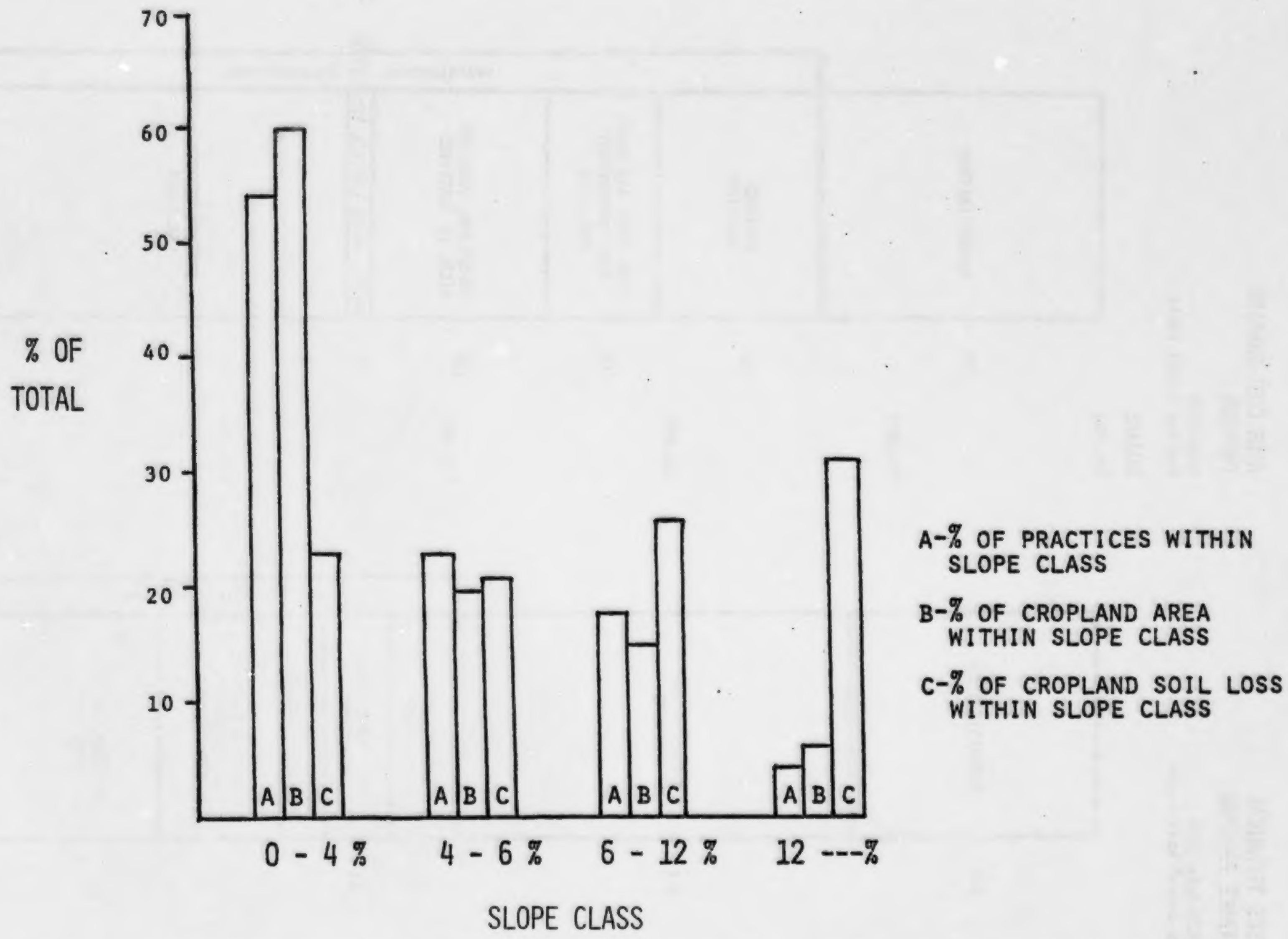

Figure 2. Distribution of Installed Agricultural Erosion Control Practices by Slope Class in Washington County, 1965 to 1975.*

*Derived from SEWRPC data and our analysis of data from a 2% survey of county lands.

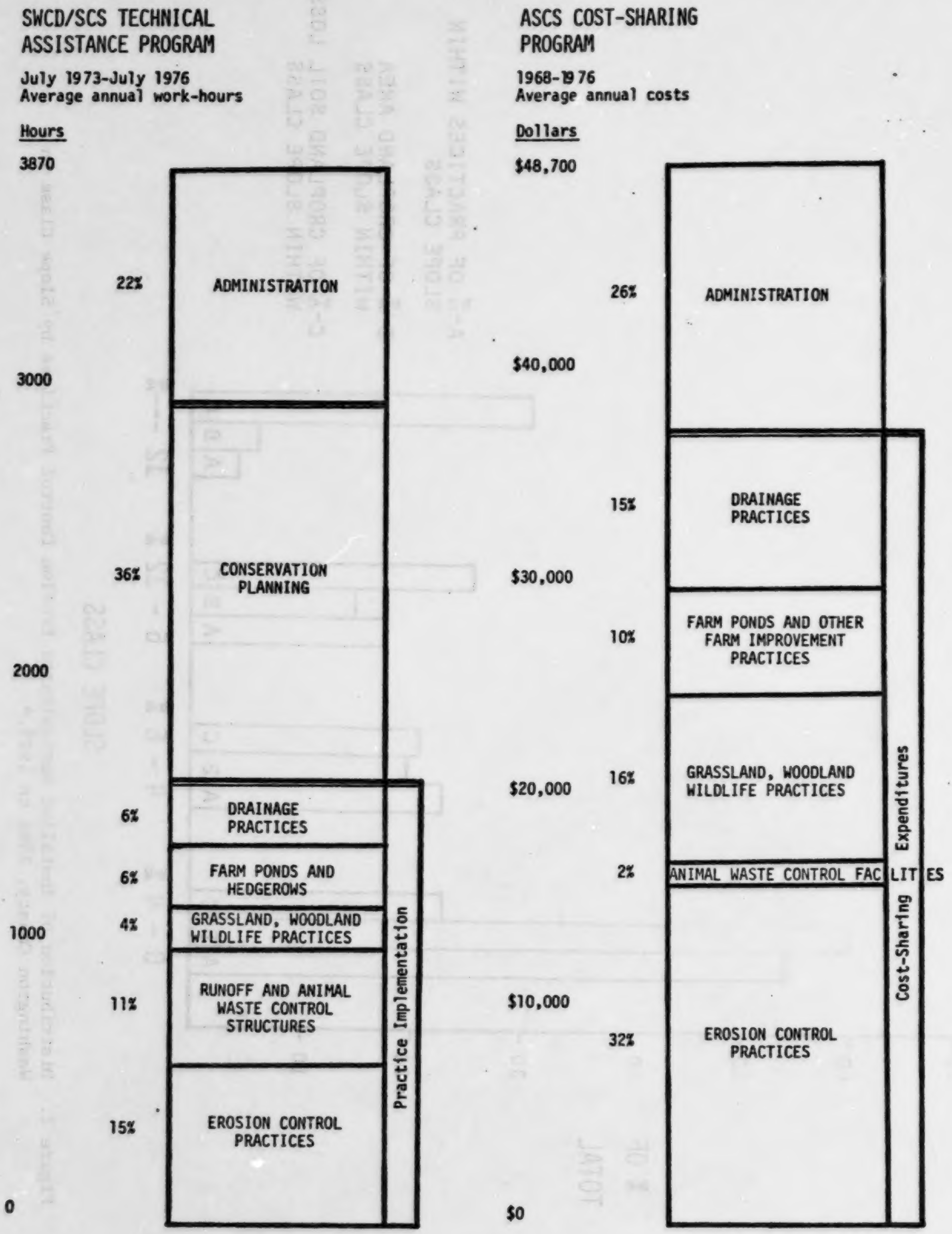

Figure 3. Allocation of Technical Assistance Effort and Cost-Sharing Funds in Washington County, Wisconsin.

and that it has developed interagency agreements and working relationships with most of the other agencies which are likely to play a role in the sediment control process. In addition, the SWCD has a major role in the recently enacted federal and state cost-sharing programs.

Furthermore, given the tradition of local control of land use, it is politically realistic to keep land use decision-making at the local level. We are not unmindful, of course, that water pollution is a matter of state and national concern, and that there is a legitimate role for state and national participation and oversight.

But we all most be very careful not to fall into the trap of guilelessly recommending a particular agency for the task, then washing our hands of the matter, hoping that all will be well. We believe there is a great danger in overselling the Districts, and that without a much greater effort to support them, they will fail.

We are satisfied that most of the erosion and sedimentation problem is caused by a minority of landowners. Clearly the key to a successful sediment control program is the ability to reach those who are causing the problem. This implies the need for a fairly intensive public information campaign. But it also suggests that hand in hand with this general informational program there must be an intensive effort to focus on a particular set of landowners, and here we're talking mostly about farmers, and to persuade them to adopt the necessary conservation practices. Given the probability that there will be no regulatory program for croplands in the immediate future, at least in Wisconsin, the techniques used to inform and persuade must be effective, or the program will fail.

We are coming to what we perceive to be the heart of the sediment control program and the key to its success. That key is the decision made by each of the scores or hundreds of individual landowners in each county who are contributing substantially to the problem. A vital influence on that landowner's decision should be the representative of the governmental agency which is responsible for the implementation of the conservation program.

Thus the key to success is not in this room, nor in the planning exercises of the 208 planning agencies, but rather it is where and when the county or district conservationist and the landowner meet. It is in the local offices of conservation districts and in the fields and farmsteads across our state. What happens when the conservationist meets the farmer in his barnyard or in his back forty is more important to the success of the sediment control program than what happens in the 208 planning agencies.

We are not saying that the 208 process is without merit and that, God forbid, all of us are wasting our time here today. Surely some element of planning and academic information exchange is essential. But we must be very careful not to substitute talking about the problem for actually doing something about it.

If you accept our conclusion that the most important actors in the effort to do something about the problem are the landowners themselves and the local conservationists who work directly with these landowners, then some rather important conclusions almost ineluctably follow. The essential conclusion is that our human and financial resources ought to be centered on the county conservationist who spends his time working in the field, rather than upon the distinguished members of this gathering. But there is a trend in our society, and we note this parenthetically, to focus more and more of our financial resources upon those of us who think about a problem rather than on those who actually do something about it. In this regard we quote from an article by Tom Bethell in the June 1978 issue of Harper's:

> It seems to me that government activity today is increasingly dominated by one of the most ominous trends of our time...: A person in our society will be paid more money, and be more highly esteemed, if instead of solving a problem materially he solves it on paper.

"At some point," continues Bethell, "problems jump across from real life onto a piece of paper. At that point they become more more pliable, remunerative, and status laden."

If you are with us this far, we would urge you to consider some of the implications of this argument. The first is that we must be willing to allocate far more resources to increasing the caliber and number of county level people who can handle the technical and administrative work and deal with the human interaction factors necessary if the program is to be successful. State and federal nonpoint programs should provide much of this money. We should note in this regard that the recently enacted Wisconsin Fund which provides a million and a half dollars for NPS programs provides $200,000 for state DNR administration and $30,000 for the State Board of Soil and Water Conservation Districts, but only $50,000 to be spread across the state for assisting county implementation programs. We suggest that this is a rather inauspicious start.

Second, and related to the first point, states must provide training and education for people who are currently on the front line. It's not realistic to expect that we could replace en masse the group of conservationists now in the field with a new set of enlightened county conservationists, even if such a mythical manpower pool existed. Besides, we recognize that there are some very competent and dedicated county and district conservationists in our counties. Our argument is that we should give them the attention and respect they deserve, and that we should work to improve the abilities of those who are not meeting the demands of the position. None of us would feel comfortable if the airlines were casual in assuring that their pilots were properly selected and trained. We would suggest that the direction of a nonpoint program is as important for the future of our country as is zipping people across our skies, and that we ought to be sure that those who direct our local soil and water conservation programs are as adequately trained.

Third, we would urge our friends in the federal agencies (we are thinking in particular of SCS, and to a lesser extent of ASCS) to consider carefully how their personnel policies affect the output of their agencies. Bureaucratic agencies have the almost inevitable tendency, as they age, to become ladened with higher paid workers who tend to focus increasingly on administrative duties rather than upon front line program implementation. This is particularly true if a limitation on numbers of personnel or budget limitations reduce the percentage of newer members as compared to older members. We should point out that this general tendency toward an increase of administrative duties is likely to be reflected by an increase in the number of strictly administrative or supervisory personnel, as well as by an increasing percentage of the time of county personnel which is spent in administrative duties. We are not now charging that SCS and ASCS have these problems, but rather suggest that since the problem is so common at least the potential is surely there.

Fourth, some kind of institutional system must be designed to reward those who are actually doing the front line work. An adequate initial salary would, of course, be a good place to start. But we know that people don't work for money alone, but also for the respect and satisfaction they get for a job well done. We can do much more to ensure that the achievements of those most responsible for increasing conservation practices are given adequate respect and compensation.

Fifth, we suggest that there is some danger in recommending that all that is necessary at the local level is some kind of on-paper coordination of related programs. We have seen too many federal and state efforts to coordinate programs which were merely symbolic and lacked substance. Don't misunderstand us: we clearly feel that an integration of county level programs is essential, and we have been moderately successful in Washington County in improving the coordination of District, SCS and ASCS programs, and those of the county planning and zoning agencies. Coordination, it must be said, is a necessary, but not sufficient condition.

The last point we wish to make concerns who is calling the shots at the local level. It is clear, we think, that in examining the mission statements of the Districts, SCS, ASCS, and Extension, we find that the Districts have the responsibility for determining policy direction at the local level. The duty of the SCS vis-a-vis the District, for example, is to provide technical assistance. It is just as clear, however, that in a great many Districts, the District Supervisors have never assumed a strong policymaking role, and that this role, in many cases, has fallen by default to the SCS District Conservationist. We are not so wedded to administrative theory and legalism that we would insist that in every case the various agencies be compelled to do only that to which they are limited by their mission statements. In many cases, the SCS, for example, has played the essential conservation role in the county, and we acknowledge that. We also recognize that nationally the Service is redirecting its efforts in recognition that previous work has been inadequate from a water quality and perhaps from a soil erosion point of view.

But we also believe that new program and policy directions require that we give greater support to local level decision-making and implementation of soil and water conservation programs, recognizing that general standards will be set by state water quality agencies. Districts should be given the resources to assume their historic role, and the other related agencies should maintain their particular areas of expertise.

This places a great burden on the District for developing long and short range plans and integrating these plans into state water quality plans; for assuming lead agency status in coordinating county level programs; for directing, in cooperation with the extension services, an intensive informational program; and for working directly with landowners to ensure implementation of needed sediment control plans. In addition, we think that the District could play a major role in coordinating their programs with those of the county and municipalities. In Washington County, for example, the District will be working with the county zoning office and, we anticipate, with the cities and villages in administering construction site erosion control ordinances. The District is the only agency with a full set of authorities and interagency agreements and working relationships to do all of this.

We, along with many others, are promoting Conservation Districts. But we must point out that without support, success of local programs cannot be guaranteed; indeed it is unlikely unless greater support is given to these Districts. We recognize that local governments have not always responded enthusiastically to social needs, and we are aware (Washington County is a good example) that the road to convincing the local units to assume responsibility can be long and hard. But we think, too, that in the long run these locally directed and implemented programs are the keys to success.

EDUCATION AND NPS POLLUTION

THE WASHINGTON COUNTY SCHOOL PROGRAM

by

Vicki K. Vine and Wes Halverson*

PRESENT SCHOOL CURRICULA AND RESOURCE ISSUES

Environmental Education is not new to schools. Conservation education has been a part of school curricula since the late 1930's. Many schools have good school camp programs at the sixth grade level and conservation courses taught in the high school. Unfortunately, the sixth grade camp is only a three day exposure to environmental topics which students participate in once during their school career. In a Washington County High School with an enrollment of almost two thousand, seventy-five students take the conservation course offered each year. Obviously, neither of these efforts alone will provide an educated citizenry able to solve complex problems concerning natural resources. Environmental education must be incorporated into subjects which all students study throughout their school career.

Curricula varies between school districts as well as within schools in the same district. Individual teacher surveys are necessary to determine the extent and content of environmental issues taught with traditional subjects. The literature lacks a good analysis of this type, but we can take a closer look at curricula in Washington County Schools.

We can gain a better understanding of curricula needs by examining a typical science curricula. Intermediate Science Curriculum Study (ISCS) (1) is used in many of the Washington County Schools. This curriculum was copyrighted in 1972 by the Florida State University. The materials are good, but it was developed more than six years ago. Current resource issues are not addressed. For example the Environmental Science segment does not mention energy issues, and in the chapter addressing water pollution the topics discussed are organic factory wastes, nonbiodegradable chemicals, sewage and phosphate detergents as water pollutants. This limited discussion of water pollution sources would not help a student understand the need for 208 Water Quality Planning. The ISCS program was developed in Florida for use nationally. It cannot explain why the City of New Berlin has a shortage of potable water to a student in New Berlin. It does not discuss the effect of millpond drainage and restoration in Hartford to students in the adjacent school. High costs of textbooks and the related lab equipment prohibit a school from frequently updating curricula.

Today's curricula does not adequately explain current resource problems with a local emphasis. The solution seems obvious--teachers must

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supplement textbook curricula with units developed locally relating to current resource issues. This may sound easier than it really is. In a questionnaire sent to school administrators, teachers and board members, two problems were identified. First, teachers often lack the technical background needed to understand complexities of resource issues. A middle school social studies teacher may have difficulty understanding 208 Water Quality Planning. In their article "Inservice Education: It Can Make A Difference" (2), Hounshell and Liggett explained, "Teachers are victims of change brought about by a very rapidly changing technological society. Undergraduate on-campus teacher education programs and even graduate on-campus programs serve a function but they cannot do it all." Many school districts devote a number of days each year to inservice education for their staff. Resource issues are seldom on the agenda during inservice education programs. This is due to the lack of interest and expertise in school curricula which has been shown by resource or education agencies.

Another difficulty identified on the school questionnaire was the lack of time available for teachers to develop new units or adapt units developed in another part of the country. A teacher would need to spend several hours developing a teaching unit from technical bulletins and information available through university extension, regional planning commissions, or other government agencies. With fiscal constraints, fewer schools can provide curricula development time for their teachers. Teacher guides accompanying resource publications would reduce the amount of time needed for teachers to incorporate material into their curricula.

After this brief look at the needs of school curricula, we can learn how the Washington County Project (WCP) school program, Water Quality and Land Use Curricula assisted teachers with development of curricula.

THE WASHINGTON COUNTY PROJECT SCHOOL PROGRAM

Early in the Washington County Project, Fred Madison, Wes Halverson and Dan Wilson began working with county schools to inform teachers about local soil and water problems. Presentations were made during teacher inservice days. This brief exposure increased teacher awareness of local issues but did not give teachers an adequate background to prepare curricula materials for their students. A one credit seminar "Understanding Nonpoint Pollution" was held during the spring semester of 1977. Participants were introduced to physical, biological and institutional aspects of soil and water problems. Part of each session was devoted to review of available curricula materials. The seminar was attended by teachers of various disciplines and grade levels as well as citizens and agency employees.

Development of curricula specifically related to the soil and water resources of the Kettle Moraine geography and its eventual adoption by public and private schools in Washington County required a still more intensive program. Wes Halverson worked closely with school administrators and teachers to write a proposal which was submitted to the Wisconsin Department of Public Instruction in January of 1977. The project was funded for Fiscal Year '77 from the Federal Elementary and Secondary Education Act of 1965, Title IV-C. This funding along with extensive support from the EPA funded Washington County Project sustained the following curriculum development project.

The project goal during the initial year was to plan school curricula enabling students to acquire knowledge, skills and attitudes relevant to land uses that affect water quality. Activities began early in May when teachers were recruited from a consortium of six private schools and six public Washington County school districts to attend a one week summer workshop. This was an intensive training program, with Washington County Project staff providing instruction. Sessions involved the study of aquatic biology, soil characteristics, Washington County resources and the land use simulation game, Water and Land Resource Utilization Simulation (WALRUS). Twenty-three teachers from 14 different schools participated; all grade levels were represented along with a variety of disciplines including social studies, communications and physical science.

The next segment of the project took place after the training workshop. Each participating teacher was paid to develop a unit related to soil and water resources which they would teach during the fall semester. WCP staff compiled soil and water learning activities developed in environmental awareness centers throughout the country. These were given to teachers for use as "raw materials" when developing units.

The units developed for elementary school students involved a variety of lessons covering many concept areas. Some lessons included the following activities. First graders discussed the importance of water after a paper bag was placed over their bubbler during a warm September day. Other students studied soil erosion and found examples near the school. Water purification was demonstrated as students poured dirty water through a container of soil. In another activity, students learned what a watershed is, which watershed their community is in and what types of land use are common upstream.

Middle school and high school students also studied soil and water resources in many different ways. A seventh grade class discovered that the cause of bank erosion on a stream adjacent to their school was students walking along the waters edge. Another middle school class studied the nearby millpond and learned about the community's restoration program. A high school communications class studied interviewing and critical listening techniques before talking with contractors about construction site erosion. In a different approach to residential development, a social studies class learned why some community members wanted to change the zoning of a residential area to prohibit apartment buildings. A role playing activity concluded the unit with a public hearing which brought out the effect of development on a small community. An upper level physics class calculated the amount of runoff from the small watershed around their school and estimated the nutrient loading rates to an adjacent stream.

As teachers prepared and taught units, valuable assistance was provided. A tour was held for teachers to become more familiar with Washington County resource problems. Teachers made contact through project staff with government agencies such as Soil Conservation Service, Department of Natural Resources and Southeastern Wisconsin Regional Planning Commission to obtain technical information and maps of specific resource problems. Pre and post tests were developed for the teachers. These tests measured student gains in knowledge, skills and attitudes.

The Elementary and Secondary Education Act (ESEA) Title IV-C funding is structured for use by one school district or a small consortium. Proposal writing procedures require communication with all public schools in the consortium as well as the private schools located within their jurisdiction. In Washington County that means 6 public school districts and 12 private schools were contacted. Proposal writing becomes very time-consuming and costly when it is necessary to work with such a large group. These problems were compounded this year as a consortium was formed from Washington and Waukesha Counties. Thirty-four public school districts and more than sixty-five private schools were contacted during the planning process. A grant proposal has been submitted to continue this project as a three year Innovative/Exemplary Demonstration Program. This project would continue curricula development and test a diffusion mechanism with "teachers teaching other teachers."

Resource Agencies and Curricula Development

The school program funded through the WCP and ESEA Title IV-C has developed an efficient procedure for curricula development and implementation. It demonstrates a technique which allows resource agencies to work closely with teachers. The curricula developed can be easily adapted by teachers in similar geographical areas. In Eugene Vivian's Sourcebook for Environmental Education (3), he states one reason conservation education has failed: teachers used a variety of resource agency staff to give talks. Vivian goes on to say that teachers were unprepared to teach ecological concepts on their own after resource agency staff left the classroom. He predicts that environmental education will also fail if the same process is used. If resource agencies are concerned about school curricula they must assist teachers. The schools are willing and anxious to participate. In a questionnaire addressed to school administrators, teachers and board members in Washington and Waukesha Counties, 94 percent of the responses indicated that "water quality impacts of land use activities should be part of the school curricula." Sixty-four percent of the responses indicated those issues were not adequately addressed in their school.

As legislation mandates that citizens are more involved in resource management we must ask if they are prepared to make or understand the decisions affecting their life-styles. We have explained why the present school education process does not give citizens an adequate understanding of resource issues and how government or public agencies can provide up-to-date curricula and assist teachers in implementing those materials with multidisciplinary kindergarten through twelfth grade curricula. We now need to consider if this can be done efficiently on a larger scale than one county. The next segment of this paper will explain a mechanism to meet the increasing needs of a democracy facing changing resource dilemmas.

LOCAL WATERSHED PROBLEM STUDIES--A NATIONAL ENVIRONMENTAL EDUCATION PROJECT

The purpose is to mount and sustain a national program of school curriculum development and teacher inservice training on water resource issues prevalent in local communities. Supporting a local approach allows for extra sensitivity toward community aspirations and toward different community social-economic histories. An expected outcome will be school teachers who understand their own community water resource problems and are able to interpret the arduous characteristics of those problems for young people.

Large and small watersheds are natural boundaries which teachers can also consider natural curriculum boundaries. Conceptual continuity logically follows from small watershed studies to larger intrastate watersheds and eventually into interstate watershed basin studies. In some regions of the country, international boundary water issues occur also and can be incorporated into the curriculum without conceptual difficulty. Climatological regions around the world and within large countries actually determine major watershed patterns and the unique biological communities which are familiar to natural scientists.

Our efforts should delineate institutional and organizational arrangements that will allow watershed curricula to evolve within climatological regions.

Study Units Build School Curricula

Before we consider procedural arrangements, let's consider the basic essence of teaching and learning. That basic essence is diversity. Students have learning needs which differ and teachers teach differently, even in the same school and about the same subject. The curricula must be flexible to meet these diverse needs. Study units on a specific resource issue and completed over a short period of time offer teachers and learners maximum flexibility.

Teachers use units to organize student learning activities, reading materials and audio visual aids. Their daily lesson plans usually follow some type of unit structure. Units are designed to teach one or more concepts and often cover many skill development objectives. Units give structure to the school learning experience without reducing the teacher's curriculum discretion. Teachers pick study units which incorporate easily because they complement regular programme syllabi and satisfy student needs.

We should encourage three types of study units. A single subject unit which can be taught by one teacher has enough learning activities to cover all the resource issue concepts but not in great depth. Other units should cover only one or two concepts but be dovetailed with units taught by other teachers in the same school. The learner receives indepth experiences from more than one teacher on the same resource issue. These are multidiscipline units and depend on good coordination between teachers. The third type are interdisciplinary units and work when teachers from different disciplines team teach the same learning activities. These units are good for projects where students spend time working in the community and contribute to resource problem resolutions.

The total school curriculum evolves by combining the various study units developed in different academic disciplines and at different grade levels. We can help teachers best by suggesting learning activities which they themselves organize into study units. We should evaluate the units and describe the learning process in participating classrooms. Following a program with the teachers as active participants will make the watershed problem studies curriculum adoptable elsewhere.

Begin the Program with Teachers--The Washington County Model

The national project staff should start first by building teacher awareness locally. Graduate level evening seminars raised awareness and gave teachers an opportunity to improve their professional status. Resource agency and nongovernment organizational publications can be used to stimulate group discussions. Inservice seminars help build a teacher constituency interested in adopting the resource issues into local school curricula.

The national project staff should complement the seminar approach with guest talks during teacher inservice programs which are normally held in the fall before school starts. The talks usually reach more teachers than the seminars but the information transfer level is much lower. They should also make a third approach through local newspapers and radio talk shows. After a sufficient campaign, school mailings should be used to recruit K-12 teachers who are willing to attend a summer workshop.

The most intensive teacher training occurs during the workshop held at an environmental awareness center. Resource agents and nongovernment organizational representatives, e.g., National Wildlife Federation, Conservation Education Association, Association for Environmental and Outdoor Education, can make the maximum impacts on teacher awareness there, and the teachers can provide valuable feedback on teaching and learning needs. This is also the time when the project staff should provide model learning activities and organize interdisciplinary teams to evaluate the activities and establish unit learning objectives. Give teachers paid time after the workshop to write their own study units based on the learning objectives agreed upon.

Pilot Test the Study Units after the Workshop

Unit evaluation should be continuous and from three different but overlapping approaches. Formulative evaluation starts when the unit learning activities are designed. The project staff should screen and select relevant environmental education activities already developed and translate current water resource research into new learning activities. Teachers will form study units from these or other learning activities after the workshop. The project staff should evaluate the teacher written units to assure continuity between the activities and the learning objectives previously established. The units will go to project clerical staff for typing before grade level evaluation. A panel of environmental education and reading consultants should review the units and confirm the grade level designation based on the psychomotor development of learners at that age.

The next two evaluation approaches occur in the classroom. The teachers who write the units will teach them during the school year following the workshop. A quantitative measurement should be made of student learning, usually in the form of pre and post tests. The score differences indicate how much students learn and the next approach will explain why the students learned. This approach is an ethnographic study of the teacher/learner milieu which occurs in each cooperating school. The descriptive case study information will make the future dissemination of the study units possible. New teachers can review the units and pick those which were taught in learning environments similar to their own.

Qualitative research can give the project staff and evaluators necessary insight about the learning milieus which occur in the three suggested unit types. If a single subject unit teacher adapts the unit procedures extensively, it may somehow affect student performance. Testing only measures performance. Observation and interviews are necessary to understand the teacher's adaptive behavior and how the students respond. Maybe the adaption stimulates enthusiasm, a student quality that is important but difficult to measure on a test.

Additional factors enter the learning milieu when two or more teachers collaborate on an environmental education program. Other teachers would want to know how these teachers cooperate to organize learning time, schedule shared students, arrange field trips or handle disruptive student behavior and classroom discipline. Answering these questions may help other teachers try the new curriculum. Without descriptive information they may be reluctant.

An Appropriate Organizational Structure

Existing state educational institutions should administer the state and regional programs of water resources curriculum development and teacher training. After the curricula are developed, a national distribution program should be administered through one federal resource agency or a coalition of agencies working with the Office of Education. Such an arrangement exists now in the Federal Interagency Committee on Education.

The university water resources centers could carry out the program objectives in each state. Acting as the administrative agencies, centers should recruit and hire teachers from state areas designated to have critical water resource issues. Members of a state advisory committee should designate the areas and practicing teachers would be hired who work in either private or public schools and are willing to help develop the curricula. The advisory committee should be comprised of representatives from the state department of public instruction, a state resource agency and the participating university. This committee could handle other project policy functions also.

The centers would coordinate the water resources information transfer occurring between resource agencies, nongovernment organizations concerned with environmental education and the participating teachers. The centers will also run the summer workshops, evaluate the study units and research the environmental education learning process.

Two types of publicity activities should be conducted to inform concerned publics about the education program. One type includes feature articles and public service announcements for local media use that inform the general public. These will help promote school environmental learning activities. A second type should be facilitated between participating students and teachers. Newsletters, slide programs and project reports are traditional methods which should be used. The centers could also make short video tape programs about the learning activities and exchange them between classrooms in different climatological regions. If six regions are established, a third grade class in one climatological area would see what other third grade classes are doing in five different climates.

One center in each climatological area should also administer regional activities. It will handle the video tape program distribution between classrooms and conduct large watershed or basin conferences that participating teachers and students can attend. The regional center should also have the major responsibility of training staff who work in each state center within the climatological area. It should coordinate curriculum development within the climatological region and balance the teacher training activities so that an equitable distribution of federal funds occurs between states and a valuable curriculum guide evolves.

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DEVELOPMENT OF RESOURCE INFORMATION FOR LOCAL DECISION-MAKERS

by

Alan Carpenter and Dan Wilson*

Public Law (PL) 92-500, enacted in 1972, expanded the national pollution abatement program by establishing provisions for control of both point and nonpoint sources of water pollution. Measures to develop and implement controls for point source pollution have progressed relatively rapidly. But as point sources have been eliminated or reduced, the significance of nonpoint sources (NPSs) has become apparent. For example, it has been estimated recently that 50% of the pollutant loadings in southeastern Wisconsin are from NPS.

PL 92-500 gave the states the primary responsibility for directing water quality protection and improvement through the areawide water quality management planning process. Implementing potential voluntary or regulatory measures designed to abate NPS water pollution is probably most appropriate at the county level.

Historically, the county has been the unit of government primarily responsible for implementation of land management decisions. Existing educational, technical assistance, cost sharing, and regulatory programs pertaining to land use activities are all under the auspices of local agencies. Because NPS water quality decisions will be closely tied to land use, it seems appropriate that the majority of NPS technical and financial aid determinations be made at the county level.

The Soil and Water Conservation District (SWCD) has been the local unit of government responsible for soil erosion control efforts. It is the SWCD's goal to plan and implement programs of local assistance which encourage the conservation and proper use of soil and water resources in the District.

The most recent amendments to the Federal Water Pollution Control Act, PL 95-217, have created a new opportunity for SWCDs to become equal decision-makers with the agencies of the USDA in determining priorities for NPS assistance to landowners and operators. This process has been developed in order to insure that the most critical water quality problems are locally addressed.

The Wisconsin legislature has recently enacted a water pollution control grant program, allocating $1.2 million for NPS projects in fiscal year 1978-79. Although this program will be coordinated by state agencies, effective planning and implementation will depend on significant SWCD participation.

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But to date, many SWCDs have not had their own staff support or the technical knowledge necessary to make soil erosion and water quality management decisions. This is due to the part-time role of SWCD Supervisors and their commitments to their own employment as well as county government in Wisconsin. Therefore, in the past, many of the SWCD's decisions have been made for them by other agencies.

Now, new decisions must be jointly made by the SWCD, USDA and state water quality agencies which consider relationships between land management and water quality. In order to set priorities for distribution of funds where they will provide the highest return in water quality, the SWCD needs to either develop on its own or be provided with background resource information.

This paper draws on the experience we are gaining in developing countywide NPS abatement strategies in conjunction with the SWCD Supervisors in Washington County, Wisconsin. It is geared primarily to the county-based technical personnel who must provide local officials with the necessary information to enable them to implement effective NPS programs. Although Washington County is detailed in this example, we believe the resource materials development process could be used as an example for other areas as well.

DEVELOPING COUNTYWIDE STRATEGIES FOR IMPLEMENTING NPS POLLUTION ABATEMENT PROGRAMS

In order to establish countywide priorities as to the direction of NPS pollution abatement programs, clearly stated definitions of the county's NPS water quality abatement goals must be formulated.

In establishing goals, federal and state water quality standards must be considered. One of the major features of PL 92-500 is the goal that all of our nation's waters would achieve "fishable/swimmable" status by 1983. In Wisconsin, the State Department of Natural Resources (DNR) has used its rule making authority to promulgate water quality standards for the state's surface water; compliance with these standards would be necessary to meet the federally mandated "fishable/swimmable" status. These standards relate to a number of parameters including dissolved oxygen, temperature, pH, bacteria, and toxic substances. Substantial portions of Washington County's waters do not meet the state's standards and are not classified as "fishable/swimmable" at the present time. County NPS programs should be directed toward meeting the "fishable/swimmable" criteria, both to comply with the spirit and intent of state and federal laws, and to maximize opportunities for receiving funding assistance.

Another crucial aspect of the prioritization process centers around values decisions. Public decision-makers are sometimes reluctant to admit that subjective considerations are part of their method of operation, but the values questions are inescapable here. For example, should priority be given to restoring marginal waters to high quality status or to protecting existing high quality areas? Should preference be given to lakes over streams? Should waters which contain unique life forms such as endangered species of fish be accorded special preference?

The entire issue of public and private use of waterbodies must be thoroughly discussed. If all users of lakes and streams would be equally benefited by NPS pollution abatement, potential user conflicts would be minimized. However, various user groups have somewhat different perceptions as to what constitutes high quality water. Water quality "improvement" which would render a lake less weedy and more suitable for waterskiing may not always benefit the local fishermen.

There are several other preference factors which are also worth mentioning. They include the degree of public access to the waterbody, the body's economic significance for recreational use and its proximity to urban areas where the majority of the potential users live.

This short discussion of values considerations is not meant to be exhaustive. Rather, it is intended to be illustrative of the types of questions which decision-makers must face.

Hopefully, decision-makers will make efforts to bring the public into the prioritization process. One of the most important aspects of public involvement is the identification of what people want from their streams and lakes. Thus, the consideration of values is central to the development of a water quality management program which has widespread public acceptance and support.

OBTAINING, ANALYZING AND COMMUNICATING WATER QUALITY AND LAND USE INFORMATION

Once the NPS management goals have been developed, information relating to land use and water quality must be gathered, analyzed and then presented in such a way that it can be readily communicated to a broad spectrum of persons. A management program must have as its base a thorough inventory of water quality for major waterbodies in the county and the point and nonpoint sources and types of water pollution.

Unfortunately, relevant data exists in a wide range of sources including governmental agencies, regional planning commissions, educational institutions, scientific literature and from local residents. Data tends to be available from a particular source along discipline lines with persons in one discipline, e.g., water chemistry, often being unaware of the existence of data in another discipline, e.g., aquatic biology. Thus, acquiring water quality information for a county involves contacting many persons and asking numerous questions.

The first step in the data collection process is to decide what types of information are needed to adequately determine existing county water quality. Table 1 shows the types of information which are useful for streams and lakes. Each of the items listed here either directly reflects lake or stream conditions or directly affects surface waters. In some counties key information concerning items in Table 1 will simply not be available, causing those data which are available to be given extra weight in decision-making processes and identifying areas in which future data aquisition is needed.

Table 1. Information Relating to Water Quality of County Lakes and Streams

A. Water Resource Information
   1. Map locations of named streams and lakes
   2. Lake morphometry--area, mean depth, maximum depth, volume, general estimate of relative size of littoral zone, navigability, water residence time
   3. Stream flow records, stream width and depth, navigability
   4. Water quality parameters--temperature, secchi depth, specific conductance, concentrations of dissolved oxygen, bacteria, phosphorus, nitrate, ammonia, alkalinity, chlorophyll-a, suspended sediment
   5. Fisheries data--significance of sport fishery, rough fish problems, presence of endangered species, fish kills, estimate of angling pressure, state agency management plans
   6. Algae and macrophyte growths--problem locations, type of affected lake users, effectiveness of any previous treatment measures, estimates of problem severity
   7. Aquatic insect sampling data
   8. Water quality indexes--trophic state index, lake carrying capacity

B. Cultural and Social Information
   1. Assessment of visitor use according to user class--fishing, boating, swimming, hunting, riparian open space
   2. Water quality objectives of local residents
   3. Activities and objectives of local groups involved in water quality issues--lake protection districts, lake associations, sportsmen's clubs, environmental organizations
   4. Economic significance of the water
   5. Availability of public access

C. Land Use Information
   1. Land topography and soil types
   2. Major land uses and management practices on steep lands and near waterbodies
   3. Location of exclusive agricultural lands
   4. Riparian development--location of platted land, tiled out septic systems
   5. Location of riparian wetlands--significance as fish spawing habitat, significance as sediment and nutrient filter
   6. Wildlife and open space--general wildlife and open space values, hunting on and around lakes, wetlands
   7. Land use regulations affection lakes and streams--shoreland and floodplain zoning ordinances, sediment control regulations, county zoning and subdivision maps
   8. Best management practice information
   9. Sources and characterization of pollution--point source locations, analysis of effluent concentration and rate of discharge (pollutant loadings), locations of evident NPS pollution problem areas such as livestock in stream or lake, barnyard runoff, cultivated steep slopes, tiled out septic systems, construction sites

Next is the problem of where this water quality-related information is located and how it can be obtained. Table 2 summarizes the principal sources of data which have been utilized in inventorying the waters of Washington County or could be utilized in other counties. Much of the information used in the formulation of a countywide water quality management program will be available from public agency personnel. Local employees of the state's natural resource department will be especially valuable both in terms of the information they can directly provide and the reports and studies with which they are familiar. Regional planning commissions, assuming one exists to serve the county, are very important sources of a number of types of water quality information ranging from water chemistry data to planning reports, maps and expert assistance. Regional planning commissions often have staff members who deal directly with water quality problems including nonpoint source pollution. Public input can also be invaluable at this stage. Individuals and citizens groups such as lake protection districts, lake associations, hunting and fishing clubs, environmental organizations, and school groups often have detailed information on specific streams and lakes.

Once the available water quality data have been assembled, they must be analyzed if they are in raw form. Water chemistry data are sometimes available in numerical form but without adequate explanation as to what the numbers imply. Tables of data, even though the numbers be valid and useful, are not suitable for management purposes until they are given meaning in terms that nontechnical persons can understand. It is imperative that data analysis be done with an eye toward the ultimate purpose: the development and implementation of a NPS pollution control program by professionally nontechnical persons.

Fortunately, many of the data that one will obtain will already be analyzed in some sort of report format. This makes the technical assistant's job somewhat easier but does not mean that the conclusions of other people should automatically be accepted, since people sometimes differ as to the significance and meaning of identical sets of data.

Still remaining is the problem of organizing the water quality information in such a way that it can be clearly and easily communicated to the SWCD supervisors,other governmental personnel and the general public. We have adopted the strategy of using maps and tables to summarize and convey the most significant water quality information. For Washington County, we selected planimetric maps with a scale of 1:48,000 which are produced by the Southeastern Wisconsin Regional Planning Commission. The 3' x 4' map size is convenient for spreading out on a table or large desk top and for displaying in small meetings.

The number of different maps should be limited so that handling them does not become a major problem. It is possible to place several types of related information on one map without creating too much clutter. However, maps made of mylar with but a single type of information can be overlain on a light table in various combinations. This flexibility is often very helpful.

We have produced several maps for the Washington County SWCD. They illustrate water resources, water quality problem areas, land slope, general land use, and livestock concentrations. With these maps it is possible to quickly ascertain where the significant bodies of water are

Table 2. Sources of Water Quality Related Information for Wisconsin Counties

1. Surface Water Resources Reports--DNR publications
   report done for each county; catalogs all named streams and lakes in county; may be out of print but probably available from District DNR offices

2. Lake Use Reports--DNR publications
   reports done for major lakes in each county; limited water chemistry data; more detailed information on soils, land use, algae and macrophytes, hydrography, fisheries

. Water Resources Data for Wisconsin--USGS publications
   annual compilation of flow, sediment discharge, sediment concentrations, and temperature from U.S. Geological Survey (USGS) stream gauging stations

4. Water Quality of Selected Wisconsin Inland Lakes--DNR publications
   annual compilation of water chemistry data for lakes throughout Wisconsin

5. Lake Classification - A Trophic Characterization of Wisconsin Lakes
   Paul D. Uttormark and J. Peter Wall, June 1975 (EPA-660/3-75-033; available from US-GPO), a study at U.W. Water Resources Center and funded by EPA; developed a lake classification system for Wisconsin lakes

6. Wisconsin Trout Streams
   Wisconsin DNR Publication No. 6-3600(74), lists all of the state's designated trout streams by county; designated trout streams are subject to more restrictive water quality standards than other streams

7. Classification of Wisconsin Lakes by Trophic Condition
   Wisconsin DNR, April 1975, also includes limited water quality data

8. Water Quality Information: Wisconsin Great Lakes and Tributary Streams
   Wisconsin DNR, August 1975, an annotated bibliography

9. Various DNR reports and studies--contact District and local DNR personnel
   a) drainage basin reports have been prepared for streams throughout Wisconsin
      may include extensive water chemistry and biological sampling data, lake data may be included, summary of condition of basin streams
   b) basin water resources plans
      tend to be somewhat general and lacking in quantitative data but can be useful background information sources
   c) reports on investigation of pollution
      tend to be somewhat dated, information on point sources, results of chemical and biological sampling near the point sources; mostly on streams
   d) research reports and technical bulletins
   e) fish distribution data--contact the DNR fish manager; these data are being computerized and will soon be accessible for entire state

Table 2. Continued

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  f) each DNR district has a staff person who is responsible for coordinating NPS pollution abatement activities; this person will be very helpful

10. Environmental Impact Statements
    major state and/or federal projects which could have major impacts on the environment require an environmental impact statement; such statements often contain a variety of useful information which relates directly to water quality

11. Regional Planning Commission Reports
    regional planning commissions prepare valuable water quality reports and sometimes cooperate with DNR in the gathering and analysis of water quality data; lists of publications are typically available from RPC offices where information on recent water quality planning activities are also available

12. Lake Management Districts
    districts frequently hire consultants to perform water chemistry and biological studies on their lakes; district DNR personnel will be able to provide information concerning the existance of the Districts

13. County Soil Surveys
    detailed surveys have been prepared or are in the process of being prepared for each county in Wisconsin; these surveys contain a wealth of useful information such as suitability of soils for various uses, detailed soil maps and areas of riparian organic soils; available from county agent

14. Aerial Photographs
    each county ASCS office has an extensive collection of aerial stereo photos which allow the viewer to visualize the landscape three dimensionally; photo scales are 1:20,000 (before about 1970) and 1:40,000 (after about 1970); these photos are very useful for locating steep slopes which are being farmed; regional planning commission may also have aerial photographs of different scales and dates

15. Maps
    Topographic maps are available for the entire state from the Wisconsin Geological and Natural History Survey in Madison; planimetric county maps of various scales are available from the county, the regional planning commission, or the state department of transportation

16. College and University Personnel
    faculty members commonly conduct research concerning water quality and may be aware of other information which would be helpful in developing the management program

17. Legal and Regulatory Information
    a) Wisconsin Water Quality Standards--from Wisconsin Administrative Code, Chapters NR102-104
    b) Wisconsin Natural Resources Laws--a compendium of all state laws related to natural resources; available from DNR, Madison
    c) County Shoreland and Floodplain Zoning ordinances--indicates what are permitted, conditional and prohibited uses in shoreland and floodplain areas; available from county corporation counsel

Table 2. Continued

d) County and town zoning maps--counties and towns which have a zoning ordinance will also have a zoning map indicating what types of land use are permitted on each parcel of land; available from county zoning officer or town zoning committee

18. Agricultural Statistics
the Wisconsin Statistical Reporting Service collects a variety of data on crop acreages, livestock numbers, and farm population from local tax assessor farm reports annually for the entire state; this information is available on a township, countywide or statewide basis

19. Land Management Data
the SWCDs, under the auspices of the State Board of Soil and Water Conservation Districts and the DNR, collected detailed land management information for approximately 2% of the land in each county during 1976-77; included were data on crop rotations, plowing methods, the utilization of conservation practices and the proximity of feed lots to waterways; while not enough land was surveyed to permit identification of specific problem areas within each county, this survey provices the best general information available on a county basis concerning the management of potential problem areas

located, which of the waters have water quality problems and what type(s) of land use activities may be contributing to the problems. This kind of countywide overview is essential for local NPS problem identification.

In addition to the maps, a written report summarizing and discussing the water quality situation in the county is recommended. The report would serve to give more specific information about particular portions of the county and would give background information useful in interpreting the maps. The written report and maps should be periodically revised, as new data becomes available.

In order to have a solid framework of understanding from which NPS programs can be implemented, local technical people and decision makers need to have at least some rudimentary knowledge of water quality, water pollution and land use problems. These terms are frequently used in discussions of NPS programs but it is likely that their meanings and relationships are not clear to everyone. On a somewhat higher level of sophistication, technical terminology, e.g., the various water quality parameters, must be set forth and clearly explained. A glossary of technical terms written with a minimum use of jargon and containing numerous examples of how the terms are used would be very helpful. An enumeration and explanation of the various types of NPS pollution sources is required background information. This listing should include sources which are known to or could reasonably be expected to occur in the county. The particular pollutants known to be associated with each of the sources should be identified. Then the general impacts of these types of pollution sources and their respective pollutants on water quality can be discussed. Clearly, decision-makers can make rational decisions concerning NPS programs only if they are familiar with water pollutants and their effects on water quality. The decision-makers must be aware of the cause and effect relationships among land use, water pollution and water quality.

IMPLEMENTING NPS ABATEMENT PROGRAMS WITHIN A SPECIFIC WATERSHED

After watersheds have been prioritized and several watersheds have been selected, the NPS programs can then be implemented in these specific areas.

While general questions of water use have been considered on a countywide level, they must be examined more closely on a watershed or subwatershed basis. Public and private use of streams and lakes varies widely from watershed to watershed and even within a watershed. For example, upper reaches of streams are typically non-navigable so boating is not an issue there, while further downstream boating may be an important activity. The type of use which a body of water receives will influence the choice of particular NPS programs appropriate for the situation.

The next step in the implementation of an NPS program in a specific watershed is the identification of the most significant sources of water pollution and water quality problem areas. We recommend the preparation of maps similar to those developed on a countywide basis but here covering only the watershed in question. These maps would show land use, soil types, topography, land cover, significant sources of pollution, and water quality problem locations. The bulk of the information necessary to produce these maps will already have been obtained in the process of locating countywide water quality data, as previously outlined.

Water quality information relevant to the watershed must be analyzed to determine how the current water quality compares to state standards and recommendations from various groups. In some situations water quality will be difficult to quantify due to the lack of data. Then either the qualitative data must be given more weight in determining water quality or a limited sampling program could be contemplated to provide at least a partial quantitative information base.

The technical specialist will also want to personally inspect the watershed to field check the published data which is available, insofar as this is feasible. The locations and types of pollution sources can be ascertained in the field after suspected pollution sources have been determined from topographic maps, aerial photographs and water quality data.

These field checks will reveal where the major water pollution sources are located and water chemistry data will indicate the current levels of various pollutants in streams and lakes. In counties where the technical specialist has the requisite background data and expertise, the calculations of the trophic state index (TSI), lake sensitivity index and permissible pollutant loading can be made. All of these calculations represent a fairly high level of sophistication, requiring someone familiar with these procedures. We do not believe that satisfactory NPS programs necessarily require the quantification of pollutant loadings, TSI and the like. However, if these factors are quantified, they can more accurately indicate the nature and extent of NPS water pollution, its effects on lakes and the likelihood that water quality problems can be abated.

After the watershed's major pollution sources have been identified and the water quality has been characterized, the mechanisms which are available for controlling the NPS water pollution problems can be determined. This involves consideration of best management practices, the level of funding available and the coordination of the activities of the local NPS implementation agency, e.g., the SWCD, and other agencies.

Developing a list of alternative management practices for NPS pollution is a relatively straightforward task. It is also fairly easy to determine what types of pollutants are controlled by each practice and what specific practices are applicable to land use activities. However, reliable evaluations of the cost effectiveness and practicality of alternative management practices are much more difficult to determine. In the short term, identification of those practices which will be considered "best management practices" (BMPs) for specific land use activities may be subject to considerable uncertainty and controversy. When these determinations are made they will be based primarily on the degree of expected improvement in local water quality. This is significant because some conservation practices which are currently supported do not contribute to NPS pollution abatement and would not be eligible for NPS pollution-cost-sharing funds.

The determination of which management practices constitute BMPs for each major type of land use will probably be made at the state level. From the array of suggested or approved BMPs, the local NPS agency can decide which BMP is most appropriate for each NPS pollution source. These decisions would reflect the practicality and cost-effectiveness of each BMP to the extent that such information is available.

Finally, the implementation of appropriate BMPs where they are needed will be the most difficult but most important part of the management program. A variety of tools exists and should be investigated. Federal, state and, in some cases, county agencies sponsor cost-sharing and technical assistance programs which can be directed toward implementing NPS water pollution abatement practices. The various units of government regulate land in a number of ways which affect NPS water pollution. Zoning has been used for over fifty years to regulate land use activities. Wisconsin is fortunate to have shoreland and floodplain zoning ordinances in all counties of the state. These ordinances recognize the public rights in lakes and streams of the state and are designed to minimize damage to the state's navigable waters caused by riparian land use.

Some counties and/or townships have enacted sediment control ordinances of various kinds. These ordinances can be especially effective at reducing sediment runoff from construction sites. Wisconsin's new Farmland Preservation Act is designed to keep prime agricultural land in production by providing tax breaks to farmers participating in the farmland preservation program. It is reasonable to assume that farmers electing to join this program may be individuals who would be interested in participating in voluntary NPS pollution abatement programs. Such potentially willing participants should be identified by county decisionmakers.

It is also important that state agencies and local governmental units coordinate their NPS water pollution activities such that all interested parties work toward a common goal. Unfortunately, such coordination has often been the exception rather than the rule, but this situation can change. Of particular importance is the cooperation between the county zoning officer and the county level NPS water pollution abatement agency, presumably the local SWCD. As mentioned previously, shoreland and floodplain zoning ordinances, plus sediment control regulations covering construction sites can have significant impact on reducing existing NPS pollution and on preventing new problem areas from developing. However, zoning regulations will be effective only if the county zoning officer and the SWCD work closely on zoning matters which could affect water quality.

As is evident, the local NPS program implementation agency does not operate in a vacuum. The decisions of federal, state and county agencies have land use implications and, hopefully, will be in harmony with those of the local NPS agency. Interagency cooperation is critical to the success of NPS programs. We envision the local NPS agency assuming the leadershop role in this endeavor.

SUMMARY AND CONCLUSIONS

Water pollution has been a matter of public concern for some time. In the past, nearly all water pollution abatement efforts have been directed at point sources such as municipal sewage plants and industrial discharges. With the passage of the Federal Water Pollution Control Act

Amendments in 1972 came the recognition that NPS pollution is a major, if not the major, cause of the deterioration of our nation's waters. Subsequently, more attention has been given to establishing programs which will reduce NPS water pollution although funds specifically earmarked for NPS abatement programs did not exist.

Beginning in 1977 the funding picture began to change dramatically. In the near future, the states will hopefully have at their disposal sizeable sums of money to abate NPS pollution. Since NPS pollution is essentially a land use problem and since land use decisions have historically been handled at the local level, we believe that the SWCD, the local agency responsible for NPS control programs, is the most logical place to vest responsibility for administering NPS control funds.

We have outlined the steps which could be taken to develop a county level NPS pollution abatement program and implement it in specific watersheds. We recognize that SWCDs do not typically possess the staff support needed to develop such a program. The acquisition and analysis of water quality data is generally beyond capabilities of part-time SWCD Supervisors.

There are several possible sources of staff support needed to develop an NPS water pollution abatement program. University Extension personnel would probably have the expertise to do the job but are generally so overburdened with current responsibilities that additional duties are often out of the question. Likewise, Soil Conservation Service (SCS) personnel would very likely posses the skills required but are also overburdened with their own tasks. Regional planning commission (RPC) staffs often have water quality management personnel but RPCs do not serve all local areas, nor is it likely that they have staff time available either.

We conclude that in light of the increasing level of responsibility which is likely to be given to the SWCDs in administering NPS programs, each SWCD requires a professional staff person accountable directly to the District to handle technical matters such as the gathering and analysis of water quality data, the preparation of resource maps and so forth. In this way, the District will not be forced to utilize valuable staff time from other agencies. It is important that the SWCD have its own staff if it is going to effectively spend public funds.

In closing we would like to quote Reuben Schmahl, Washington County Board and SWCD Chairman as follows: "Our efforts in 'nonpoint' pollution control become very complicated. Any attempt to implement a corrective program involves many people and agencies of varied interests to carry on a study and implement acceptable objectives in a practical manner. I am of the firm belief that Soil and Water Conservation District Boards are logical entities to take leadership and accept responsibility to achieve reasonable and effective locally administered programs dealing with land use and water quality."

RED CLAY SLOPE STABILITY FACTORS

Little Balsam Creek Drainage 92°15'W, 45°30'N
Douglas County, Northwestern Wisconsin

by

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Data collected in this investigation outlines the mineralogical character and range of mechanical behavior of the red clay and establishes the Little Balsam drainage as representative of many of the geologic and engineering conditions in the Nemadji River watershed and other parts of the red clay plain which borders the southwestern side of Lake Superior

Man's removal of the forest cover, modification of the natural drainage and other practices have promoted drying of a 5-7 foot thick surface zone in the Little Balsam drainage and elsewhere in the red clay area. Slope instability results in two well defined types of situations: (1) when decreased moisture leads to fissure development in the brittle surface zone which, although strong because of its low matrix moisture content, slides on or flows over plastic clays below when moisture accumulates in the fissures, and (2) when an increased slope angle and lack of toe support result from stream erosion of the base of a slope having the characteristics outlined in (1).

The changes which promote drying also affect the rate and quantity of runoff, thereby increasing lateral and vertical erosive capacities as stream volumes and velocities increase. Even in localities where forest cover remains along portions of a stream course the entire natural relationship between streams and bank materials has been altered within the memory of those now living. The result has been an acceleration in the time rate of bank failure and an increase in its frequency throughout the red clay area. The topography will continue to evolve under the influence of the awesome power of natural processes, but if man uses the land according to a plan which incorporates realistic agricultural and engineering practices their rate of operation can be slowed and a new equilibrium established. It is therefore recommended that:

1. Channel deepening in any part of the drainage basin be minimized through methods to retard upland runoff and through minimization of drainage diversion from the upland surface.

2. Slope toes be protected by vegetation or by other means especially in reaches not now being actively eroded.
3. Efforts be made to maintain and improve vegetative cover and accumulation of a water retaining mat of organic-rich materials which protect slopes from sheet erosion while maintaining soil moisture at more nearly the levels found below 10 feet.
4. Land buyers/owners be warned of the continuing evolution of slopes steeper than 10-15° and appropriate set-backs be made according to the slope characteristics.

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THE SIGNIFICANCE OF VEGETATION IN MODERATING RED CLAY EROSION

by

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Vegetation contributes to the abatement of soil erosion by depleting soil water content, intercepting and redistributing incoming precipitation, retarding runoff, maintaining soil porosity and increasing soil strength. Although these plant properties are accepted generally, the relative contributions of each applied to a specific problem are speculative. Studies performed during the past 2-1/2 years have sought to define the capacity of vegetation to moderate erosion of the red clay zone of the Nemadji River Basin which empties into western Lake Superior. These investigations have had two main thrusts: 1) the influence of the vegetation on soil water content and 2) the distribution and strength of plant roots in the region.

Soils

The soils of the Nemadji River Basin are derived from glacial till and lake sediments. The clays of lacustrine origin, the predominant soil type, are of the montmorillonite type ≤ 2 μ diameter. Beach sands, unsorted sand, silt and clay from glacial drift comprise the remaining soil components. Generally, the lacustrine clay zones are well drained whereas the glacial till zones are poorly drained (1, 2).

The clays, remarkably uniform throughout the study area, have a bulk density ($g \cdot cm^{-3}$) ranging between 0.94 and 1.12 with a mean of 1.05. The Plastic Limits range from 20-30%. The Liquid Limits typically range from 40-80% (3). Auger borings reveal relatively uniform moisture content >40% for depths greater than 3 m.

Vegetation

Presettlement: As revealed from survey records of 1860 (4) the Nemadji Basin as a whole was dominated by white pine (*Pinus strobus* L.) with an importance percentage of 27.2. Almost one-fourth of the white pine were 60 cm DHB or larger, a size unmatched by any other tree in the forest. Spruce (*Picea* spp.), tamarack (*Larix laricina* Du Roi) and birch (*Betula* spp.) were other species contributing significantly to the character of the forests. As a synthetic unit, the forests were moderately dense with 187 trees$\cdot$ha^{-1}. The average diameter of the trees was near 28 cm.

Discernable patterns of forest communities are difficult from gross surveying data. At the minimum it was possible to distinguish flood plain forest types exemplified by ash (*Fraxinus* spp.); upland vs ravine forests indicated by significantly larger tree diameters in the ravines; and on a large scale white pine and tamarack forests. Computer generated distribution maps identified a white pine community restricted

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chiefly to the elevations <330 m which approximates the lake bed of glacial Lake Duluth. Similarly tamarack tended to occupy the sandy, poorly drained soils outside the former lake bed (4).

Contemporary Vegetation: Human impact on the vegetation of this region which has been significant since the logging activities of the last century. After the forest cover had been removed, much of the area was converted to agricultural use. This usage seemingly reached its maximum extent during the 1920's and 1930's. Gradually, agricultural interests have diminished and much of the area is reverting to forest cover. The extent of these activities is reflected by the proportions of various vegetation types (Table 1) occurring in the subbasins (Little Balsam Creek and Skunk Creek). Though similar community types exist in the two subbasins, field sampling data reveal generally dissimilar vegetation (Table 2). These differences are indicative of varying land use practices between the subbasins. Generally the vegetation patterns of the Nemadji Basin as a whole show similar evidence of disturbance. Of the forested stands, the successional pattern from aspen to the maple-basswood unit has potentially interesting consequences to the erosion question (Figure 1).

Table 1. Area Represented by Different Community Types in the Two Study Basins

	Little Balsam		Skunk Creek	
	Area (Acres)	% of Total	Area (Acres)	% of Total
Woodlands				
I. Aspen Hardwoods	418	13.3	201	3.0
II. Northern Hardwoods				
A. Aspen/Birch Dominant	962	30.5	2999	45.2
B. Oak/Maple Dominant	409	13.0	288	4.3
C. Maple/Basswood Dominant	147	4.7	73	1.1
III. Conifer	70	2.2	138	2.1
IV. Ravine Forest	182	5.8	213	4.7
V. Plantations	28	0.9	43	0.6
Wetlands				
VI. Hardwood Swamp	378	12.0	600	9.0
VII. Conifer Swamp	21	0.6	231	3.5
VIII. Bog	64	2.0	10	0.2
IX. Marsh				
A. Wet Shrubland	102	3.2	206	3.1
B. Marsh			7	0.1
Fields				
X. Abandoned				
A. Herbaceous	2	0.1	41	0.6
B. Shrubby	29	0.9	28	0.4
XI. Agricultural Fields	542	10.8	1455	21.9
XII. Construction Zone			7	0.1

Table 2. Comparison of Diversity and Similarity for Stands (Little Balsam/Skunk)

Stand	Shannon-Wiener	Simpson	Index of Similarity
Aspen	1.454/1.197	.071/.098	0.21
Aspen-Birch	1.551/1.556	.051/.058	0.53
Ravine Forest	1.232/1.333	.107/.098	0.44
Wetland Hardwoods	1.055/1.579	.218/.041	0.26
Agricultural Fields	1.605/1.613	.032/.037	0.59

The aspen tend to be more open than other types, having ∼200 trees·ha^{-1} communities to ∼450 trees·ha^{-1} in the maple basswood. Since the diameters of all communities were similar ($\bar{X}$=19.7 $\pm$1.47 cm) the aspen stands also had the smallest phytomass. A significant correlation is the inverse relationship between aspen I.P. and total stand density (trees·ha^{-1}) ($r = -0.87$, significant at 0.01 level). Linear regression analysis of shrub density and herb biomass reveals no trend ($r = 0.01$). The correlation of tree density and shrub density was not significant ($r = 0.46$), nor is there any demonstrable relationship between shrubs and aspen importance ($r = 0.03$). No significance was found between tree density and herb phytomass ($r = 0.05$). Likewise there is a positive, but not significant trend between density and aspen importance percentage ($r = 0.64$). If shrub density and herb phytomass are relativised (expressed as a percentage of the maximum value) and combined, there is a moderate inverse trend, but no significant correlation ($r = -0.69$) between tree density and the shrub-herb component (5).

Documentation of these trends would require additional data points, not currently available. The data suggests, however, that the increase in phytomass of the herbs to be expected under a more open canopy in the less dense stands of aspen may be less than anticipated. Additional work to clarify the potential relationships between aspen and ground cover has begun.

METHODS

Soil Moisture

Soil moisture conditions were monitored weekly during April-November in 1976 and 1977 in the following vegetations: aspen, birch, fir, maple, pine, grazed pasture, abandoned agricultural field (grass covered) and bare soil. Three replicates in each vegetation type were measured by gypsum conductivity blocks and the Beckman Soil Moisture bridge at depths of 5, 15, 30, 60 and 100 cm. Calibration in units atmospheres (Ψ soil) was achieved with a Wescor C-52 Soil Psychrometer.

Stemflow-Throughfall: Thirty-eight trees representing quaking aspen, paper birch, red maple, red oak, balsam fir, black spruce and white pine were prepared for monitoring stemflow (SF) and throughfall (TF). Rain gauges were placed in a fixed pattern under the canopy to detect the amount of TF to be compared to the amount of precipitation

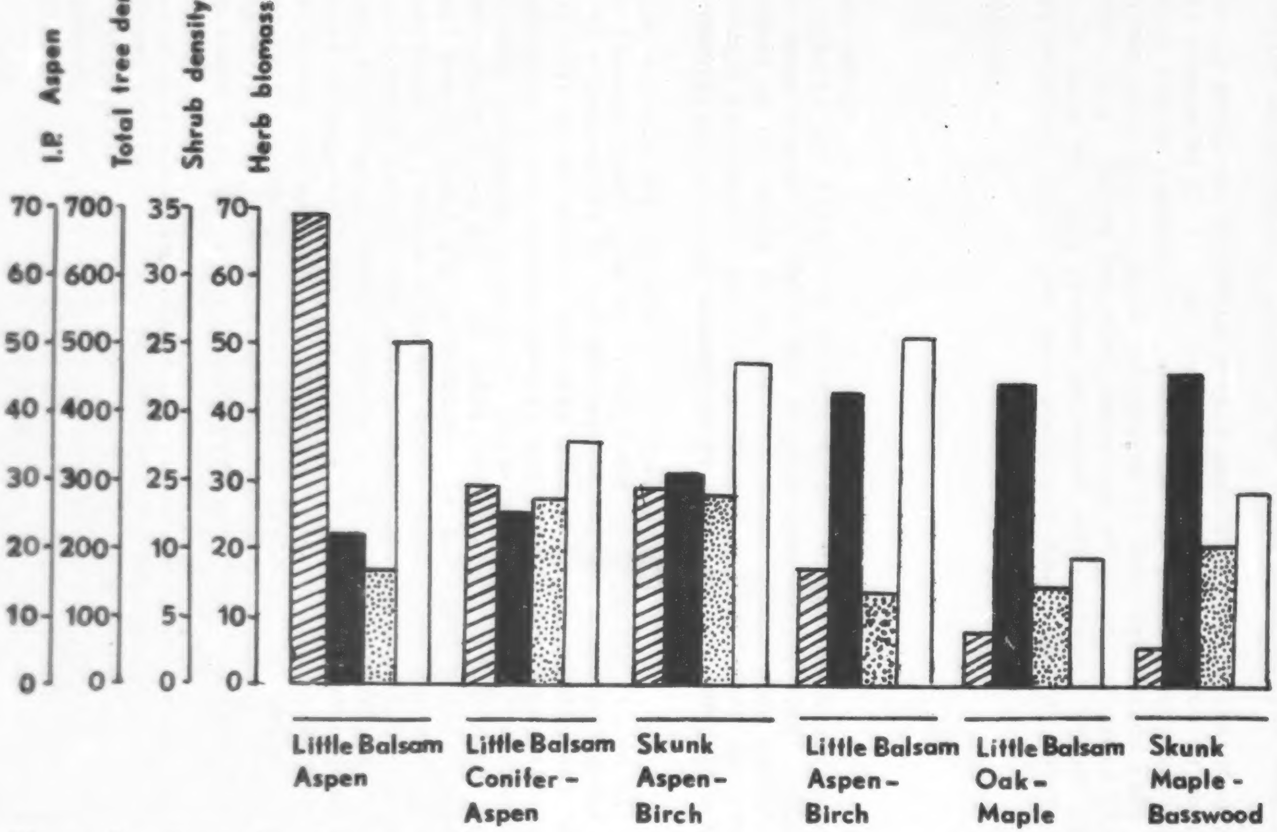

Figure 1. Community Structure of Successional Stands Ranked in Order of Decreasing IP of Aspen.

measured in gauges in the open (6). Three gauges were placed along each of the cardinal directions to collect TF of the inner canopy, the mid-canopy and the outer canopy. A polyurethane collar was molded to the trunk of each tree to enable collection of SF water following procedures described by Likens and Eaton (7). During the 2 year period 35-50 rain periods were measured for SF and TF depending on the time of installation for the various specimens.

Surface Runoff: The volume of surface runoff and the amount of sediment was determined during the summers of 1976 and 1977. Five replicate enclosures (1 m x 1 m) were positioned in each of the following four conditions: grassed with apparent slumping, grassed stable, wooded with apparent slumping, and wooded stable. Runoff was collected in sunken 20 l carboys with an overflow connected to an 80 l plastic garbage can. After rainfalls the volume of runoff was measured and the amount of sediment load was determined from aliquots of the runoff. Each aliquot was filtered through a 0.45 μ millipore filter and the dry weight of sediment was obtained. Considerable variability in both the volume of runoff and the sediment load occurred for similar amounts in rainfall. Thus for analytical purposes, the data was organized in groups according to the amount of precipitation (i.e. $\leq$ 15 mm, 16-30 mm, 31-45 mm, 46-60 mm, >60 mm).

Root Excavation

Excavation sites for determining root distribution patterns were located semi-randomly adjacent to transects established to quantify soil slumping activity. Along such transects 5 quadrat sites (0.5 m x 1.0 m) were excavated at 10 cm depth intervals to a total depth of 50 cm. Visible root[1] material was collected from each layer and later washed to remove adhering soil particles. Additionally, a subsample of the soil from each layer was brought to the lab to estimate the quantity of the finer root materials. Quantitative data (mass and calculated root lengths) were obtained for 12 diameter size classes. Linear regression analysis was employed to describe trends and patterns of root distributions.

Root Tensile Strength

Fresh root segments (5 cm length) from various species were subjected to a steadily increasing force applied along the longitudinal axis. The breaking strength was determined with Ametek force gauges mounted horizontally. Linear regression equations of log tensile strength vs. log diameter were calculated for each specimen. Generally more than 60 measurements per specimen were used to develop the equations.

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[1] For convenience we have included rhizomes in the root materials.

RESULTS

Stemflow-Throughfall

The amount of water channeled down the stem of any given species was quite variable and exhibited no significant correlation with the amount of incident precipitation. Grouping of the trees by species and tree size provides some discrimination. For example, mid to large size birch with its curled bark tend to have small amounts of stemflow compared to other deciduous species of similar size. Trees with side branches appressed to the main stem ($\Theta < 30^\circ$) have larger volumes of stemflow than trees with spreading branches. Although the volume of stemflow often exceeds 20 l for rains of 1 cm or more, this redistribution represents a very small percentage of the incoming rain. If stemflow is divided by the projected area of the canopy the stemflow typically is <1% of the incident precipitation.

Unlike SF, TF was correlated strongly with incident rainfall. Significant differences are apparent among the different positions of the canopy (inner, middle, outer) for many specimens. Also major differences exist among the species. Generalized features of TF (Figures 2 and 3) are obtained from the linear regression analysis of TF and incident rainfall.

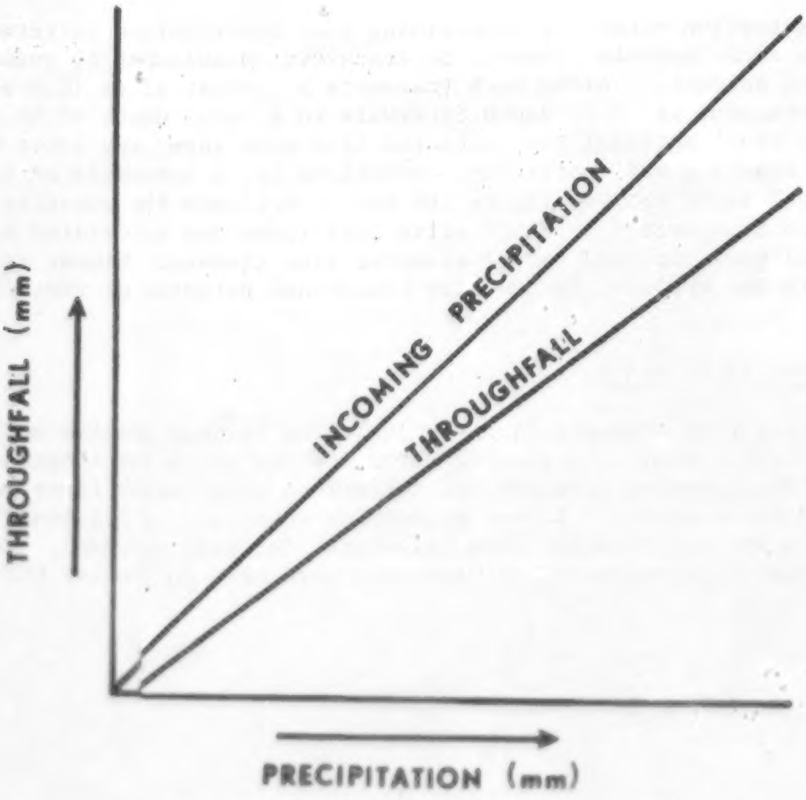

Figure 2. Relationship Between Precipitation (cm) and Throughfall (% of Incoming Precipitation).

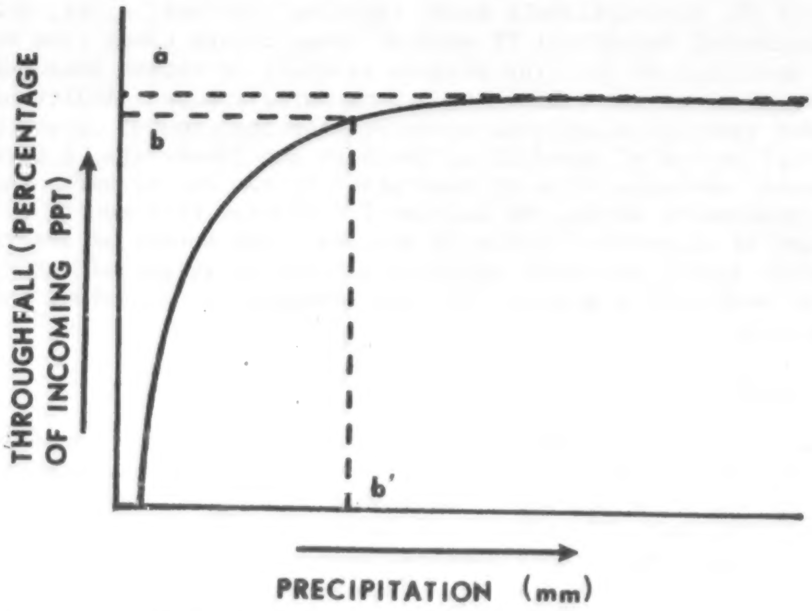

Figure 3. Relationship Between Precipitation (cm) and Throughfall (cm).

Three patterns (Figure 4) appear related to general differences in morphology.

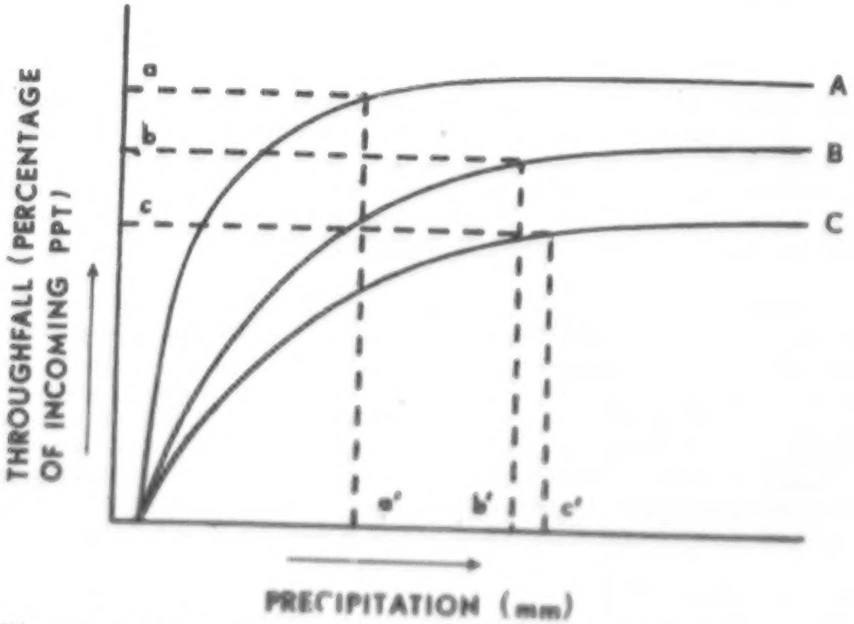

Figure 4. Throughfall Patterns for Three Canopy Types.

More open canopies such as aspen and birch are typified by larger amounts of TF, intermediately dense canopies like oak, maple, white pine have substantial amounts of TF whereas dense canopy trees like spruce and fir have limited TF. The minimum rainfall to obtain measurable TF ranged from 0.5 mm for a birch to 3.2 mm for a spruce. Additional interception (precipitation that never reaches the ground) occurs during the initial period of rainfall as the bark and leaves absorb water. Experimental measures of water absorption by samples of bark, indicate a rapid absorption during the initial 2-4 minutes of exposure to water. Saturation is approached within 30 minutes. The amount of absorption (saturation level) was quite variable (10-60% of weight of water to weight of bark with a mean of 30%) and revealed no consistent patterns among species.

Soil Moisture

The unusually dry summer of 1976 provided excellent conditions for monitoring the effects of vegetation cover types on soil moisture. Depletion of soil moisture was considerable in all plots as precipitation declined. The most effective cover types with respect to the depletion of soil moisture were grazed pasture, abandoned field with predominant grass cover and aspen (Figure 5). Much less effective were fir, pine, maple, and bare ground (Figure 6).

Following light rains the surface soils (top 5 cm) with less cover (bare soil and grazed pasture) recharged more extensively than soils with more cover, reflecting the significance of rainfall interception by vegetation. With larger rains the bare soils were less efficient in capturing the precipitation than the more vegetated soils. The vegetated soils tend to have a more porous structure resulting from a higher organic carbon content, from root penetration and subterranean animal activity which promotes percolation. In the more compacted bare soils the surface is readily saturated and excess moisture is lost as surface runoff.

The summer of 1977 was wetter than normal with numerous small rains occurring throughout the months of April through June and mid July through October. Except for a brief period in early July the soils in all plots remained relatively saturated (Ψ soil = -1.5 to -4.0 atmos.) throughout the 1 m profile. The surface soils (upper 15 cm) began to dry down in the same pattern as observed in 1976.

The measures of red clay consistency (3) demonstrate a rather narrow range of soil stability with respect to soil moisture content. Our measures of the permanent wilting point of the soils indicate that plants can draw down the soil water content to $11.8 \pm 0.3\%$ thereby inducing soil fracturing. Large fissures (>2 cm wide and several meters long to depths of 15 cm or more) were common in the grassy areas in 1976. Many of these fissures remained throughout 1977. During wet periods when precipitation exceeds Evapotranspiration (P/E >1) the soils exceed the liquid limit and are subject to liquid flow.

Weather data for the Little Balsam subbasin appears to fluctuate more than at the nearest official weather monitoring site, the Duluth International Airport. For the months May-October rainfall in the

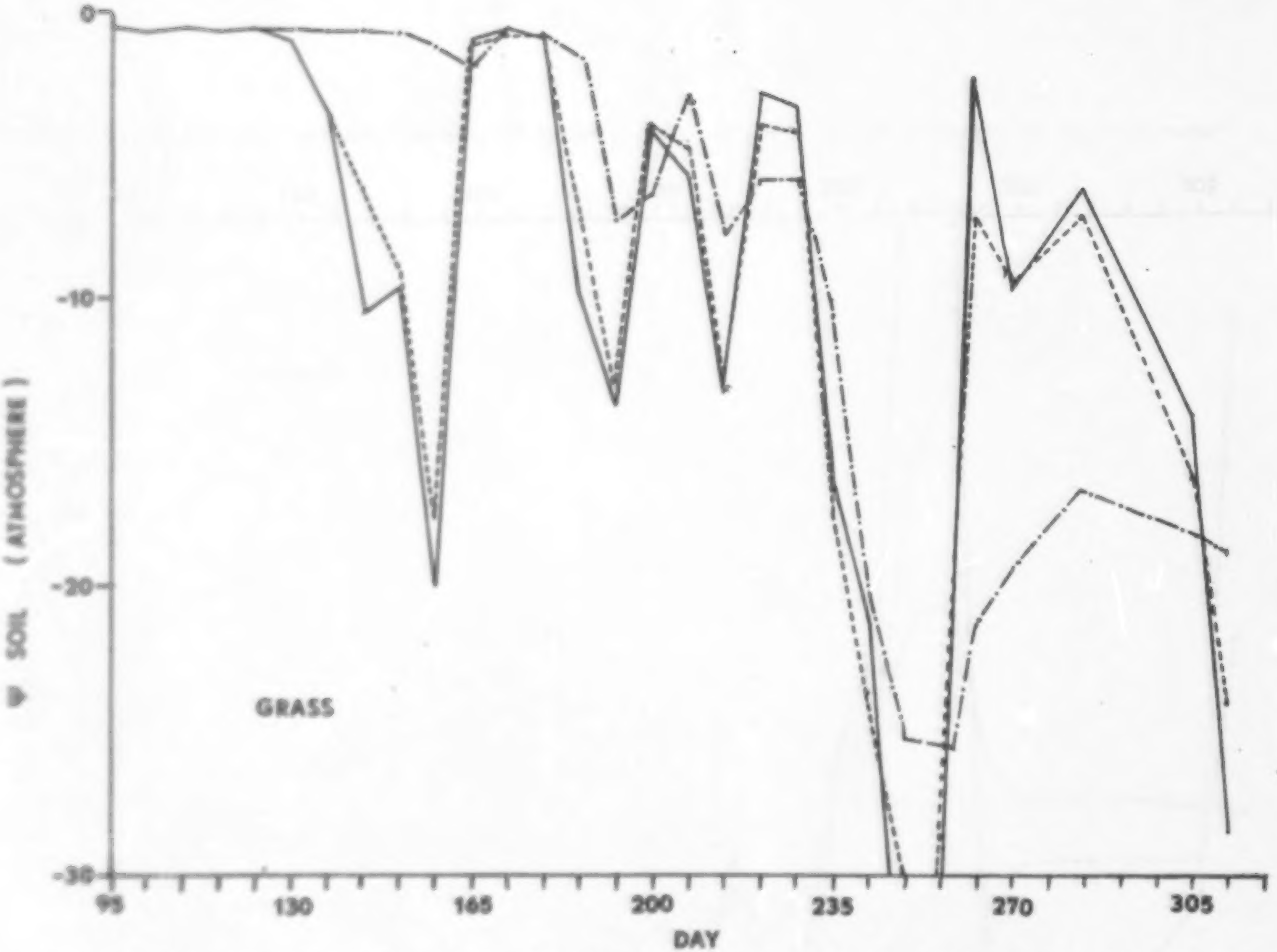

Figure 5. Weekly Soil Moisture Conditions (Ψ Soil) at 5 cm (——), 15 cm (---) and 30 cm (-·-) Depth.

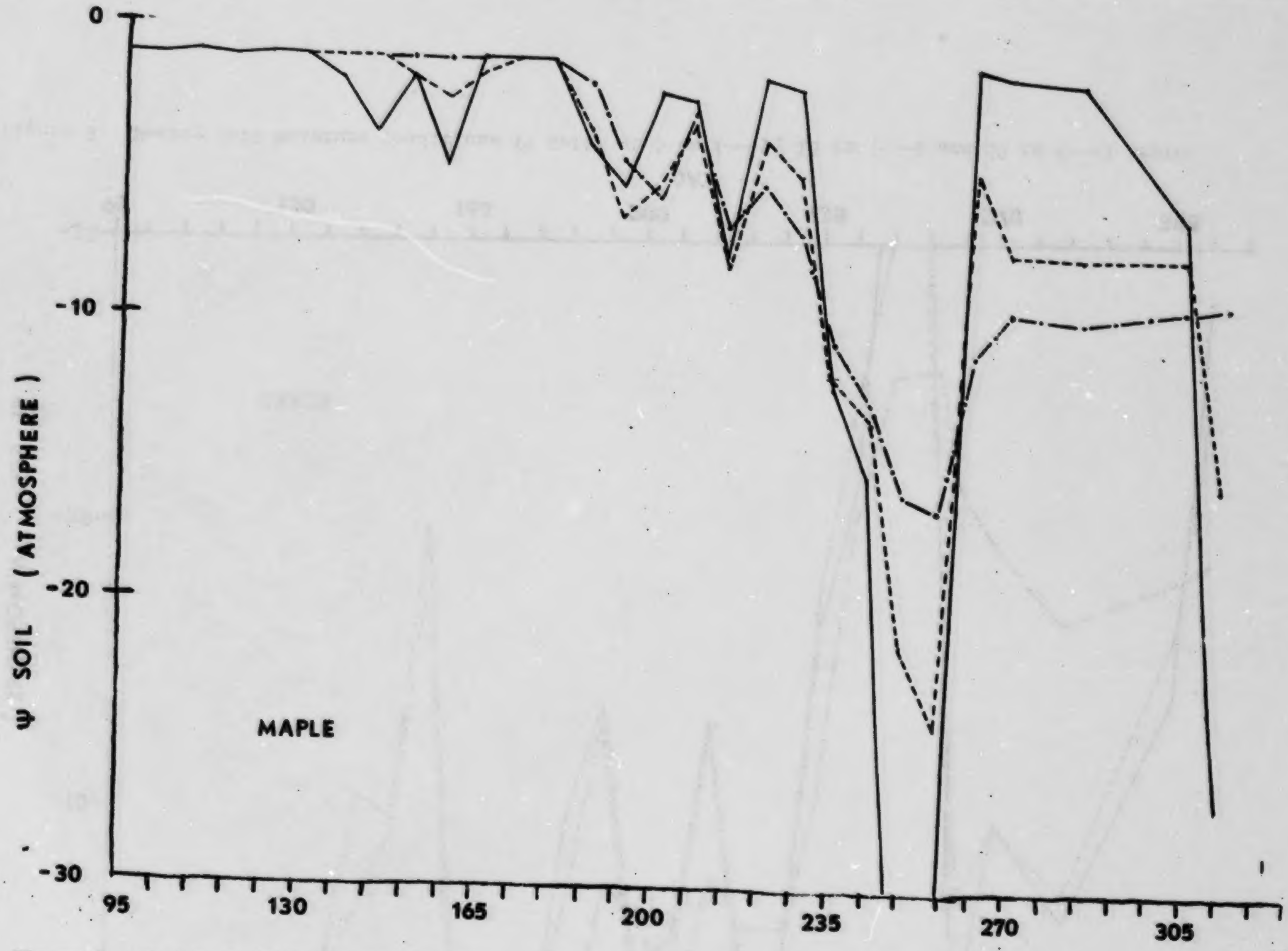

Figure 6. Weekly Soil Moisture Conditions (Ψ Soil) at 5 cm (——), 15 cm (---) and 30 cm (-.-) Depth,

Little Balsam sites was 242.6 mm for 1976 and 741.2 mm for 1977 (8). At Duluth rainfall for the same periods were 332.0 mm and 604.8 mm respectively. The 30 years mean precipitation for the period is 526.5 mm (9). For the western Lake Superior region the typical annual evapotranspiration potential is less than the expected annual precipitation. The probability of evapotranspiration exceeding precipitation is only 1 year in 50 (10).

Measurements of soil slumping indicates the major activity occurs during the spring thaw period, especially if the soil was wet prior to freeze-up (11). Plants develop the potential to remove significant amounts of water from the soil only after the expansion of leaves, which in this region occurs in mid to late May. A comparison of the soil moisture conditions of 1976 and 1977 suggest that plants can have a significant draw down of soil moisture only during the drier than normal years. In unusually dry years certain vegetation covers, especially the grass and sparse aspen areas, the soils dry below the plastic limit creating future erosion problems.

Surface Runoff

The volume of runoff in areas with slumping was considerably higher than in stable areas for both grassed and wooded areas (Figures 7 and 8) and tended to increase logarithmically with increasing amounts

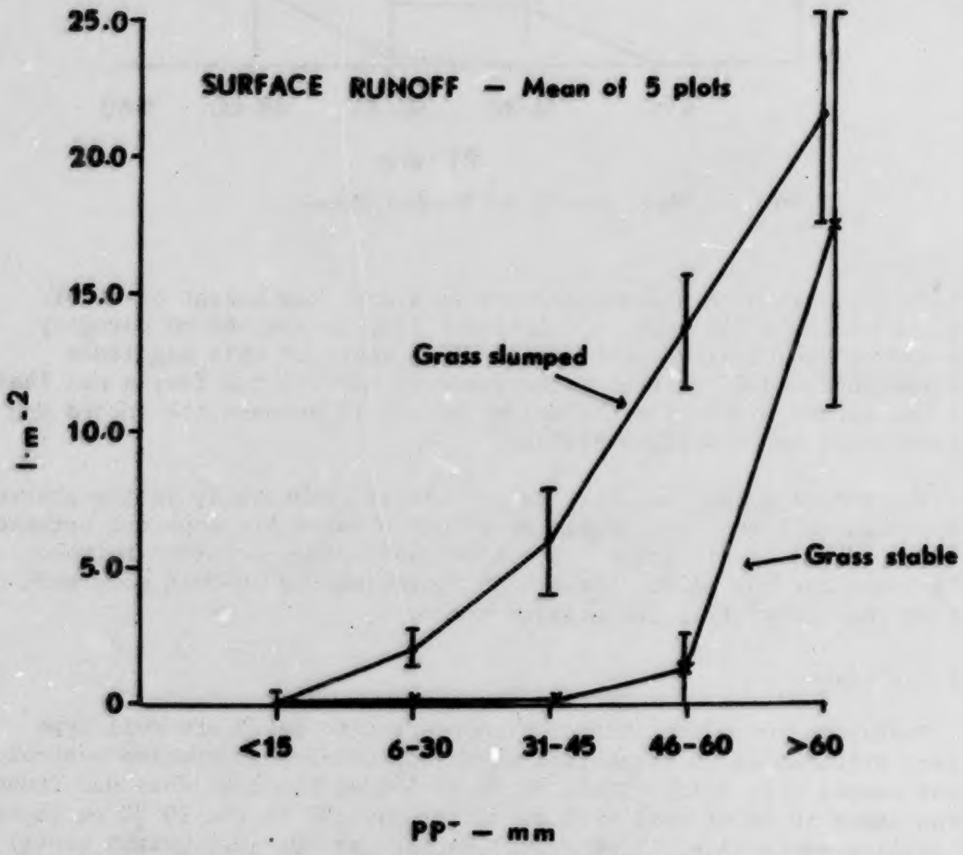

Figure 7. Mean Surface Runoff of Grassed Areas.

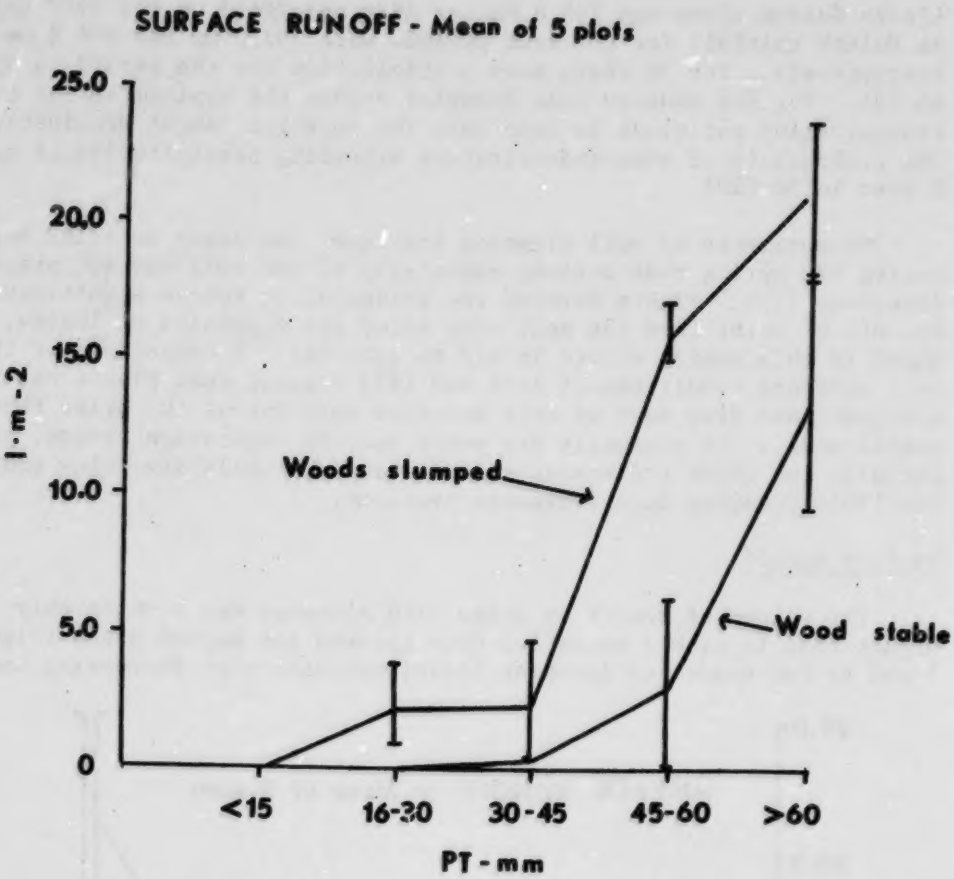

Figure 8. Mean Runoff of Wooded Areas.

of rainfall. In both grassed and wooded areas, the amount of runoff from the stable soils appears relatively high in the >60 mm category. This may be due to circumstances as only 3 rains of this magnitude were recorded and 2 occurred after the soil surface had frozen and leaf fall had begun. Otherwise the volume of runoff between the wooded and grassed areas is remarkably similar.

The sediment load was extremely variable, especially in the grassed areas (Figures 9 and 10). Again major differences are apparent between the slumped and stable areas. The major difference occurred between the grassed and the wooded areas with approximately 10-fold more sediment in the runoff from the grassed areas.

Root Distribution

Trends in root distribution with respect to depth and soil type reflect differences in vegetation cover significant to erosion control. In the wooded clay soils (Table 3) up to 55% of the root mass was found in the upper 10 cm of soil with an additional 20% in the 10-20 cm layer. For smaller roots (i.e. <1 mm diam.) as much as 70% (dry weight basis) occur in the upper 10 cm and 90% in the upper 20 cm of soil. Although

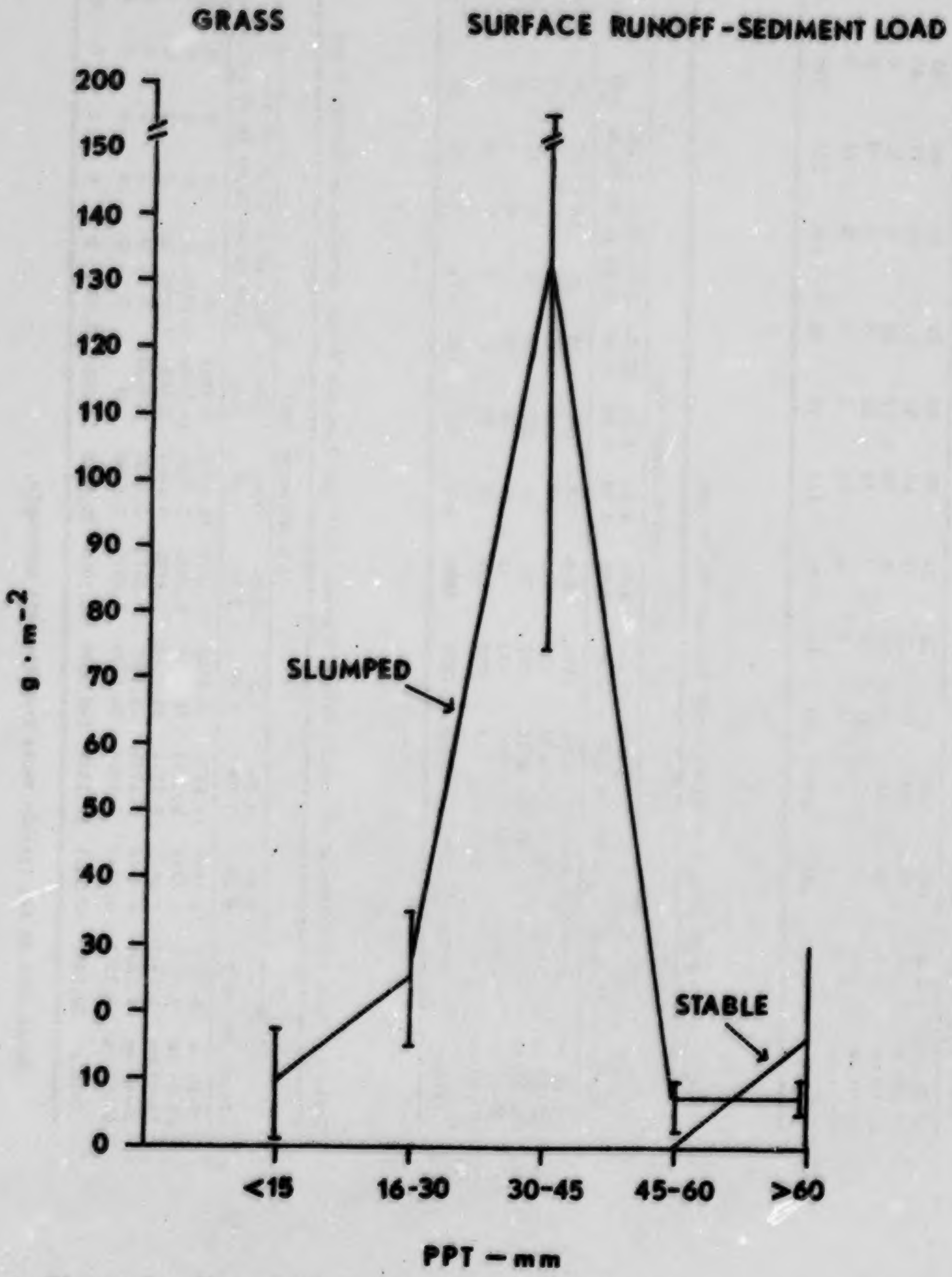

Figure 9. Mean Sediment Load of Grassed Areas.

Table 3. Mean Root Biomass of Skunk Creek Transect No. 6 (Gram Oven Dry Weight Rounded to Nearest Gram)

Depth	Root Diameter (mm) <0.5	0.5-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	5.0-9.99	10.0-14.99	15.0-19.99	20.0-24.99	25.0-29.99	≥30	Totals
0-10 cm	159	105	46	29	22	24	39	20	45	34	80	198	807
10-20 cm	40	42	28	15	12	12	47	32	30	74	11	40	327
20-30 cm	9	20	18	9	10	8	30	12	10	0	31	0	160
30-40 cm	6	10	9	11	4	3	14	12	0	0	0	0	71
40-50 cm	4	7	5	5	6	4	11	3	0	0	14	0	62
Totals	221	187	107	71	56	51	142	78	86	109	137	239	1489

Table 4. Mean Root Length of Skunk Creek Transect No. 6 (cm)

Depth	Root Diameter (mm) <0.5	0.5-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	5.0-9.99	10.0-14.99	15.0-19.99	20.0-24.99	25.0-29.99	≥30	Totals
0-10 cm	203002	31478	4310	1175	438	328	164	33	36	18	27	38	241048
10-20 cm	51136	1279	2630	629	237	158	208	81	29	35	5	9	67950
20-30 cm	12556	6329	1711	362	211	86	125	28	9	0	11	0	21341
30-40 cm	8069	3062	903	453	75	45	54	19	0	0	0	0	12683
40-50 cm	6052	2231	513	229	120	54	76	10	0	0	6	0	10393
Totals	280816	55803	10069	2850	1083	673	627	168	74	53	49	47	352317

Table 5. Mean Root Biomass of Little Balsam Transect 5 (Grams Oven Dry Weight Rounded to Nearest Gram)

Depth	Root Diameter (mm) <0.5	0.5-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	5.0-5.99	10.0-14.99	15.0-19.99	20.0-24.99	25.0-29.99	≥29.9	Total
0-10 cm	26.1154	11.0469	29.8678	39.8549	17.5660	15.6290	2.7817	0	0	0	0	0	142.8617
10-20 cm	2.0617	2.2247	8.0153	26.9410	6.6026	2.2124	10.1146	1.4050	0	0	0	0	59.5773
20-30 cm	1.1529	2.0415	8.2147	31.6661	5.8784	0.4987	3.3887	1.7715	0	0	0	0	54.6125
30-40 cm	0.5204	0.8948	5.1335	25.9891	6.1627	0.2030	0.0550	0	0	0	0	0	38.9585
40-50 cm	0.3553	0.8342	4.9019	24.6179	7.8969	2.0798	0	0	0	0	0	0	40.6860
Totals	30.2057	17.0421	56.1332	149.0690	44.1066	20.6229	16.3700	3.1765	0	0	0	0	336.6960

These data do not include roots from the soil subsample.

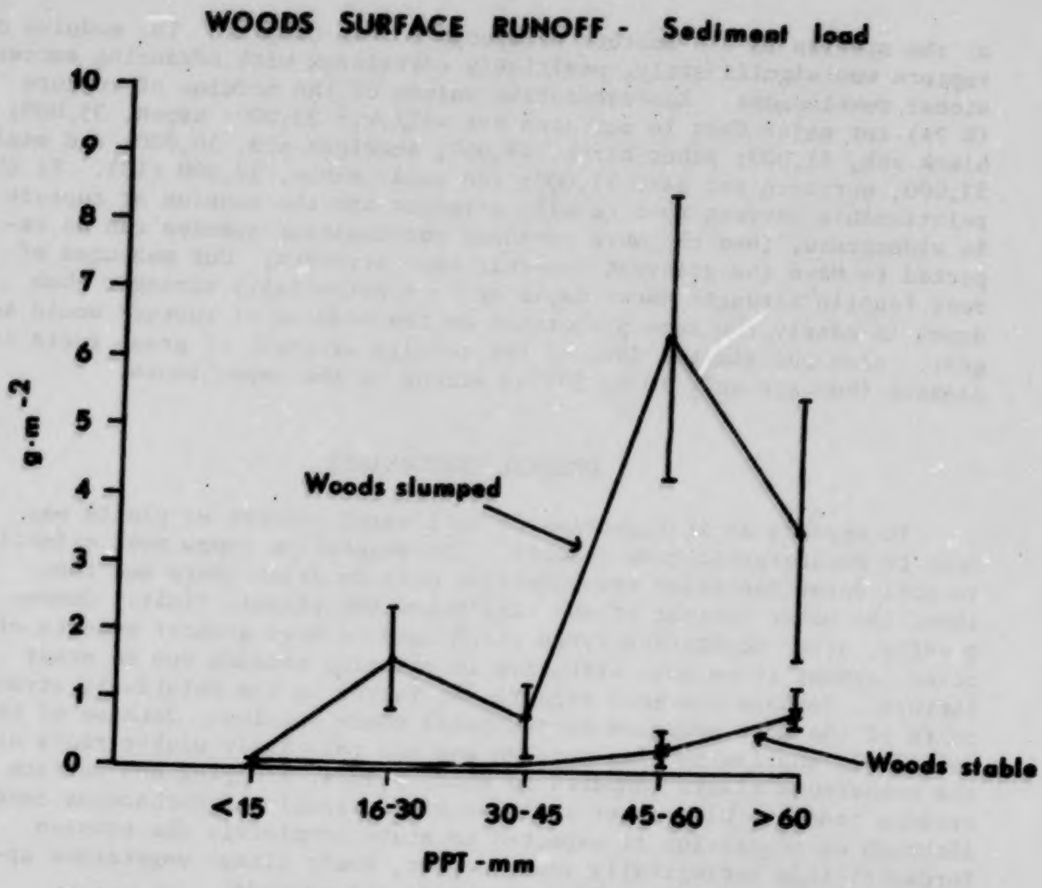

Figure 10. Mean Sediment Load of Wooded Areas.

the linear regression of root mass (Y_m) and soil depth (X) describes a significant relationship ($Y_m = 839.9 - 180.5X$; $r = -0.696$), the relationship between total root length (Y_1) and soil depth is even more pronounced (Table 4; $Y_1 = 5.54 - 0.35X$; $r = -0.906$). By comparison, the grassy slopes contain approximately 1/5 to 1/3 as much root mass as the wooded areas (Table 5). Furthermore the upper 10 cm harbor as little as 30% of all roots in the 50 cm profile. Generally the grassed areas have a rather uniform distribution throughout the remainder of the profile. This uniformity appears to result from the distribution of Equisetum rhizomes, while the grass roots diminish rapidly with depth.

A few of our sites were located on sandy soils. The distribution pattern of roots was more diffuse and thus less predictable in the loose soil. No statistically significant trend between root mass and soil depth was present ($r = -0.211$), but a significant trend between root length and soil depth was described ($Y_1 = 5.0531 - 0.1442X$; $r = -0.663$).

Root Tensile Strength

The tensile strength of small roots of various woody species appears to be correlated with the strength of wood as measured by the modulus of rapture for those species. Wells (12) demonstrated a relationship among numerous morphological features and the successional position of the species in the Eastern Deciduous Forest Complex. The modulus of rupture was significantly, positively correlated with advancing successional development. Representative values of the modulus of rupture (K Pa) for major taxa in our area are willow,[2] 33,000; aspen, 35,000; black ash, 41,000; paper birch, 44,000; American elm, 50,000; red maple, 53,000; northern red oak, 57,000; and sugar maple, 57,000 (13). If the relationship between root tensile strength and the modulus or rupture is widespread, then the more advanced successional species can be expected to have the greatest per-unit root strength. Our measures of root tensile strength shows maple to be substantially stronger than aspen in nearly the same proportion as the modulus of rupture would suggest. Also our limited data of the tensile strength of grass roots indicates they are only 10 to 50% as strong as the aspen roots.

GENERAL CONCLUSIONS

It appears as if reduction of soil water content by plants may lead to counterproductive results. The vegetation types most effective in soil water depletion are effective only in drier years and then lower the water content of the clay below the plastic limit. Consequently, other vegetation types which tend to have greater amounts of cover, appear to be more effective in reducing erosion due to other factors. Perhaps the most significant factor is the relatively stronger roots of the more advanced successional woody species. Because of the relatively shallow rooting pattern and the relatively weaker roots of the herbaceous plants compared to woody plants, slumping and surface erosion tends to be greater in areas with predominant herbaceous cover. Although no vegetation is expected to abate completely the erosion forces of this geologically young region, woody climax vegetation appears to be most capable of ameliorating the process.

RECOMMENDATIONS

The following guidelines for management of vegetation in the red clay zone are intended to be simple, feasible practices that will lead to significant reduction of erosion.

-- On construction sites, vegetation should be established at the earliest opportunity.

-- Where possible, woody species should be phased into the herbaceous cover.

-- Among woody species, the more advanced successional species are preferred, largely due to their greater root strength.

-- Along stream banks and associated drainage areas, soil stability equations should be employed to demarkate the "100-year safe zone." Within this zone, all human activity that arrests or reverts the successional process should be prohibited. This includes logging and unnecessary construction unless these activities are consistant with forest management practices that promote advanced successional stands.

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[2] This value is for black willow but is presumed to be indicative of the wood strength of willows in the red clay area.

-- In critical erosion sites, the establishment of advanced successional woody vegetation should be actively promoted by acceptable methods of forest management including planting of seedlings, selective cutting, and fertilizer application.

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THE EFFECTS OF RED CLAY TURBIDITY AND SEDIMENTATION ON AQUATIC LIFE IN THE NEMADJI RIVER SYSTEM

by

P. W. DeVore, L. T. Brooke and W. A. Swenson

Red clay erosion in southwestern Lake Superior has been a natural process along shorelines and in tributary streams and rivers since decline of lake levels following the Pleistocene period. Exposure of the unconsolidated glacial lake deposits resulted in fairly high and constant rates of erosion long before man began to alter the landscape. Rates of erosion along the Lake Superior shoreline have averaged up to 3.1 meters/year since 1938 (1) with contributions of 2×10^6 metric tons of red clay soils annually (2). An additional 5.6×10^5 metric tons are resuspended in the lake due to wave action and 3.2×10^5 metric tons are added by stream erosion (3). There is evidence that rates of erosion were accelerated by logging operations during the late 1800's, but this increase probably did not add significantly to the impact of the red clays on the Lake Superior ecosystem.

Despite persistent turbidities and sedimentation in southwestern Lake Superior, the fishery has been historically productive. Lake herring seem to have thrived as the clays add nutrients to the somewhat sterile environment and the reduced photic zone concentrates the plankton (4). Not until introduction of rainbow smelt resulted in another planktivore selecting this same concentrated food source, which included larval herring, did herring stocks collapse (5,4). Walleye continue to benefit from the moderate turbidities in the lake and river mouths. The resultant low light intensities in the relatively productive inshore areas and broad shallows such as the Duluth-Superior estuary allow walleye stocks to reside in these waters without retreating to deep water sanctuary. The walleye population in southwestern Lake Superior is one of five stocks in the entire Great Lakes not experiencing declines (6). Red clay turbidity is a possible contributor to this stability.

Nutrient inputs to Lake Superior due to red clay erosion may have had a significant impact on production before settlement of the basin, but orthophosphate loading today from shoreline and stream erosion (302 metric tons annually) is only 3.7% of the contribution from the Duluth-Superior metropolitan area alone (7). Contributions of metals and other solutes are also insignificant when compared to present loadings from other sources (8). An exception to this is silica, which is loaded at a rate of 14,400 metric tons per year. This may be an important element in maintenance of diatom populations, the primary group of phytoplankton in Lake Superior. Silica availability in Lake Michigan may have contributed to limitations in diatom production in those waters (9).

The only detrimental effects which have been well identified from moderate rates of sedimentation are those on salmonid reproduction. Substantial rates of flow through the gravel are required for selection by the female as a spawning site (10,11) and for survival of eggs and emergence of fry (12,13,14). Reviews of adverse effects on the benthic fauna (15) do not identify any effects of low level deposition, perhaps because such studies are rare or absent in the literature.

The study of aquatic life in the Nemadji River System, which produces 89% of the total erosional material from streams entering Lake Superior from Wisconsin, was begun with the realization that red clay erosion: 1) had minimal direct physical impacts on aquatic life in Lake Superior, 2) resulted in spatial redistribution of organisms and affected species interactions in Lake Superior, 3) was a fairly general characteristic of the Nemadji watershed with few areas severely aggravated by man (90% of the watershed is second growth forest), and 4) had turbidity levels which seldom exceeded 100 ftu's (65 ppm), minimal in comparison to suspended solid concentrations in waters where previous studies concerning the effect of erosion and sedimentation had been conducted.

The effects of turbidity and sedimentation on aquatic life have generally been studied in situations where there are massive movements of soils (e.g. logging operations, poor agricultural practices over large areas) or a source of inorganic sediment (sand pit washing, mining clay wastes, etc.). The burden of sediment which is discharged into stream and river systems under these conditions has afforded excellent opportunities to assess the effects of extremely high levels of stream sedimentation on aquatic life (16,17,18). Few studies, however, have measured the effects of erosion and the resultant turbidity and sedimentation which occur naturally in a young river system flowing through highly erodable bed materials such as is the situation in the glacial lake deposits characterizing the Nemadji River Basin. This study offered the unique opportunity to assess the effect of relatively low level sedimentation in such a system.

NEMADJI BASIN STUDY AREA

The Nemadji River Basin includes 740 km^2 (460 mi^2) in Carlton and Pine Counties, Minnesota and Douglas County, Wisconsin. The basin is essentially a level plain representing a portion of the abandoned lake bed of glacial Lake Duluth. Lake deposits of clay, silt and sand comprise the central portion of the Nemadji watershed. The Nemadji is a young river meandering through a level plain of highly erodable lake sediments. Land use is 90% second growth forest. The area was clearcut in the early 1900's and is now predominantly regrowth of aspen, birch and some pine (19).

Two tributaries to the Nemadji River were selected for implementation of erosion control measures and were of primary interest to this study. These are the Skunk Creek Basin in Minnesota, a relatively high sediment-producing watershed covering 17.2 km^2 (10.7 mi^2), and Little Balsam Creek in Wisconsin, a moderate sediment-producing basin covering 9.7 km^2 (6 mi^2). Skunk Creek remains relatively turbid year-round. Stream discharge varied from 0-5.78 cms (0-204 cfs) in April-September 1976. The average gradient is 6.25 m/km (33 ft/mi). Little Balsam Creek is a relatively clear trout stream which maintains a more stable discharge [.02-1.87 cms (.75-66 cfs) in November 1975-September 1976]. Average gradient is 20 m/km (105 ft/mi). Land use within both watersheds is of relatively low intensity. The primary sediment producing problems are stream bank and roadside erosion.

Eight study sites were selected and used for the entire September 1975–May 1978 study period. These included two sites on the Nemadji River, two sites on Little Balsam Creek, two sites on Skunk Creek, one site on Empire Creek and one site on Elim Creek. Empire Creek has similar discharge and water temperatures to Little Balsam Creek, but has no clay in the watershed. Elim Creek is a tributary to Skunk Creek. Five other sites (four in the Nemadji River and one in Balsam Creek) were initially included in the study but were eliminated after the first year due to redundancy of the information gained (see 20 for a more complete description of study sites).

RESULTS AND DISCUSSION

Three products of erosion which affect the aquatic ecosystem are nutrient input, turbidity and sedimentation. Each of these factors has possible effects associated with it, as outlined in Table 1. Studies conducted in the Nemadji River System have addressed most of the items in this outline.

Table 1. Potential Effects of Erosion on Aquatic Ecosystems

- Nutrient Input
- Turbidity
  - Reduced Light Penetration
    - Primary Production
    - Rooted Plants
  - Reduced Visibility
    - Inhibits Sight-Feeding Fish
    - Organism Interactions (Behavioral Changes)
  - Increased Substrate for Microorganisms
- Sedimentation
  - Direct Effects on Organism
    - Clogging Gills
    - Inundation
  - Change in Substrate
    - Cover Rocky or Riffle Areas
    - Eliminate Interstitial Space
    - Change Character of Substrate in Pools

The purpose of this report is not a detailed summary of the methods and analyses of all aspects of our studies. It is rather a summary to identify the probable consequences of erosion in this system and potential remedial actions which might be undertaken to minimize any adverse effects. A more detailed report will be available in September 1978.

Chemical and Physical Characteristics

Potential adverse impacts of red clay erosion on water quality, aside from the problems created by clogged water intakes, have been identified as oxygen depletion and nutrient inputs (21). Adequate monitoring of oxygen levels in red clay areas has been conducted to demonstrate that oxygen is not depleted by the red clays or associated organic compounds. The lowest level of oxygen saturation recorded in this study was 54.6% (Table 2). Average saturation levels at sites with the highest mean annual turbidities (Skunk Creek) exceeded 92%.

Bahnick (7) showed that orthophosphate is removed from water by red clay in solution if it exceeds an equilibrium concentration of 0.06-0.13 mg/l. Turbid water sites on Skunk Creek had average orthophosphate concentrations within these ranges (Table 3). Clear water sites (Empire and Little Balsam Creeks) had generally higher average orthophosphate levels than turbid water sites with the exception of Elim Creek and Skunk Creek downstream from Elim which were affected by barnyard runoff.

Table 3. Range and Means (in Parentheses) of Nitrite, Nitrate and Ortho- and Total Phosphate for Ice-Free Periods Between August 1976 and April 1978.

	NO_2 (ppb)	NO_3 (ppb)	$O-PO_4$ (ppb)	$T-PO_4$ (ppb)
Little Balsam	0.0[a]-74.50 (6.72)	0.0[a]-533.80 (88.47)	0.0[a]-868.37 (98.43)	0.0[a]-1219.17 (514.63)
Empire	0.0[a]-37.90 (3.28)	0.0[a]-263.54 (42.62)	0.0[a]-886.88 (96.10)	0.0[a]-1094.54 (307.03)
Skunk Above Elim	0.0[a]-13.53 (0.85)	0.0[a]-56.38 (18.04)	0.0[a]-246.52 (39.76)	60.3-610.95 (242.35)
Skunk Below Elim	0.0[a]-42.30 (2.35)	0.0[a]-76.30 (18.91)	0.0[a]-535.57 (99.65)	38.8-1168.79 (463.43)
Skunk at Hanson Dan	0.0[a]-12.20 (1.02)	0.0[a]-126.93 (28.13)	0.0[a]-216.37 (62.93)	42.8-1160.54 (326.82)
Elim Below Dam	0.0[a]-25.92 (5.29)	0.0[a]-161.21 (36.48)	0.0[a]-793.26 (200.59)	0.0[a]-1028.92 (623.07)
Elim above Dam	0.0[a]-26.40 (5.45)	0.0[a]-338.88 (67.76)	0.0[a]-649.52 (144.23)	46.0-890.84 (540.06)

[a] Below minimum detectable levels.

Red clay, although not contributing significantly to orthophosphate levels in the watershed, may serve to transport these nutrients to Lake Superior when runoff from domestic and barn yard wastes causes phosphate concentrations to exceed the equilibrium concentration. Nutrient contributions from the Nemadji River watershed are relatively insignificant when compared to those from municipalities, however.

Primary Production

Standing crop of periphyton on artificial substrates was measured

Table 2. Range and Means (In Parentheses) of Turbidity, Dissolved Oxygen, Percent Oxygen Saturation, Conductivity, and Temperature at Eight Sites in the Nemadji River System for the Period May 1976-October 1977.

Site	Turbidity (ftu's)	Dissolved Oxygen (ppm)	% Oxygen Saturation	Conductivity µmho/cm	Temperature °C
Nemadji River (near mouth)	12-220 (51.6)	6.0-11.7 (8.6)	54.6-96.4 (80.2)	82-300 (186.4)	1.2-22.2
Nemadji River (Central Portion)	7-300 (45.3)	6.0-13.4 (10.1)	54.6-112.0 (92.1)	99-280 (187.4)	1.3-25.0
Nemadji River (Central Portion)	4-460 (51.5)	7.0-13.4 (10.5)	64.2-119.1 (96.1)	70-309 (172.8)	1.6-23.3
Little Balsam Creek (Near Mouth)	2-63 (10.5)	9.2-12.8 (11.0)	88.2-123.1 (99.0)	48-182 (123.1)	1.8-18.2
Little Balsam Creek (Headwaters)	2-9 (4.6)	6.7-12.2 (9.4)	57.4-107.6 (84.0)	30-179 (96.4)	1.5-16.2
Empire Creek	1-28 (6.4)	9.4-12.8 (10.6)	85.1-105.7 (93.0)	47-191 (114.1)	1.5-12.8
Skunk Creek (Above Elim Creek)	12-200 (40.6)	8.8-12.4 (10.3)	80.0-113.0 (94.2)	43-232 (139.3)	0.5-21.1
Skunk Creek (Below Elim Creek)	10-500 (54.2)	7.0-12.7 (10.0)	70.5-122.1 (92.9)	59-238 (154.0)	0.3-21.9
Elim Creek	4-500 (68.3)	8.0-12.8 (10.7)	79.4-124.6 (98.2)	110-276 (174.9)	1.9-20.0

in Little Balsam, Empire and two Skunk Creek sites during the ice-free months from late 1976 through August 1977 using chlorophyll a as an estimator. Glass slides (25 mm x 76 mm) at two depths (4 and 30 cm) and two positions (horizontal and vertical) were used as standard substrates for collection and analysis. Thirty centimeters was a fairly moderate maximum depth but was felt representative of the maximum depth of riffles where most of the available substrate for periphyton production occurs. Horizontal substrates were used to identify the effect of sedimentation on production. Standing crop measurements do not necessarily reflect actual levels of primary production in these tributaries, but was effective in assessing the effect of existing conditions within each tributary on production on a standard substrate.

Standing crop of chlorophyll a was plotted with data from 1977 preceding that from fall, 1976 to demonstrate seasonal trends in primary production (Figure 1). Production in the Skunk Creek sites increased earlier in the spring and decreased earlier in the fall than the other test sites. This was a result of minimal ground water discharge. Stream discharge in Skunk Creek depends primarily on surface runoff, and water temperatures are very responsive to ambient air temperature. Empire and Little Balsam Creeks have much greater ground water discharges, resulting in more stable flows and cooler temperatures which are not as responsive to air temperatures.

Empire Creek is the only watershed with no clay soils, and sedimentation was minimal except when discharges were high enough to transport sand to the water surface. The angle of orientation of the slides had little effect on production at this site. Differences in standing crop due to orientation were fairly pronounced at the other three sites, with differences about as great on Little Balsam Creek, which is characterized by very low turbidities, as on the relatively turbid Skunk Creek sites. Minimal quantities of silt and clay decrease periphyton populations on surfaces which retain sediment.

Reduction in standing crop of periphyton with depth appears to be as great in the clear-water Little Balsam Creek as the turbid Skunk Creek sites. Turbidity at levels encountered in Skunk Creek during this study apparently does not have a great effect on production at 30 cm. Estimates of total annual production derived from measuring the areas under the curves show significantly lower levels only in Empire Creek, the only site with no clay in the watershed (Table 4). Skunk Creek

Table 4. Relativized Values for Total Annual Production of Periphyton on Glass Slides at Two Depths and Two Angles of Orientation in Empire, Little Balsam and Skunk Creeks.

Depth (cm)	Empire Creek		Little Balsam Creek		Skunk Creek (above Elim Cr.)		Skunk Creek (below Elim Cr.)	
	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
4	0.39	0.43	0.61	1.00	0.65	0.95	0.46	0.94
30	0.37	0.37	0.55	0.78	0.48	0.78	0.39	0.63

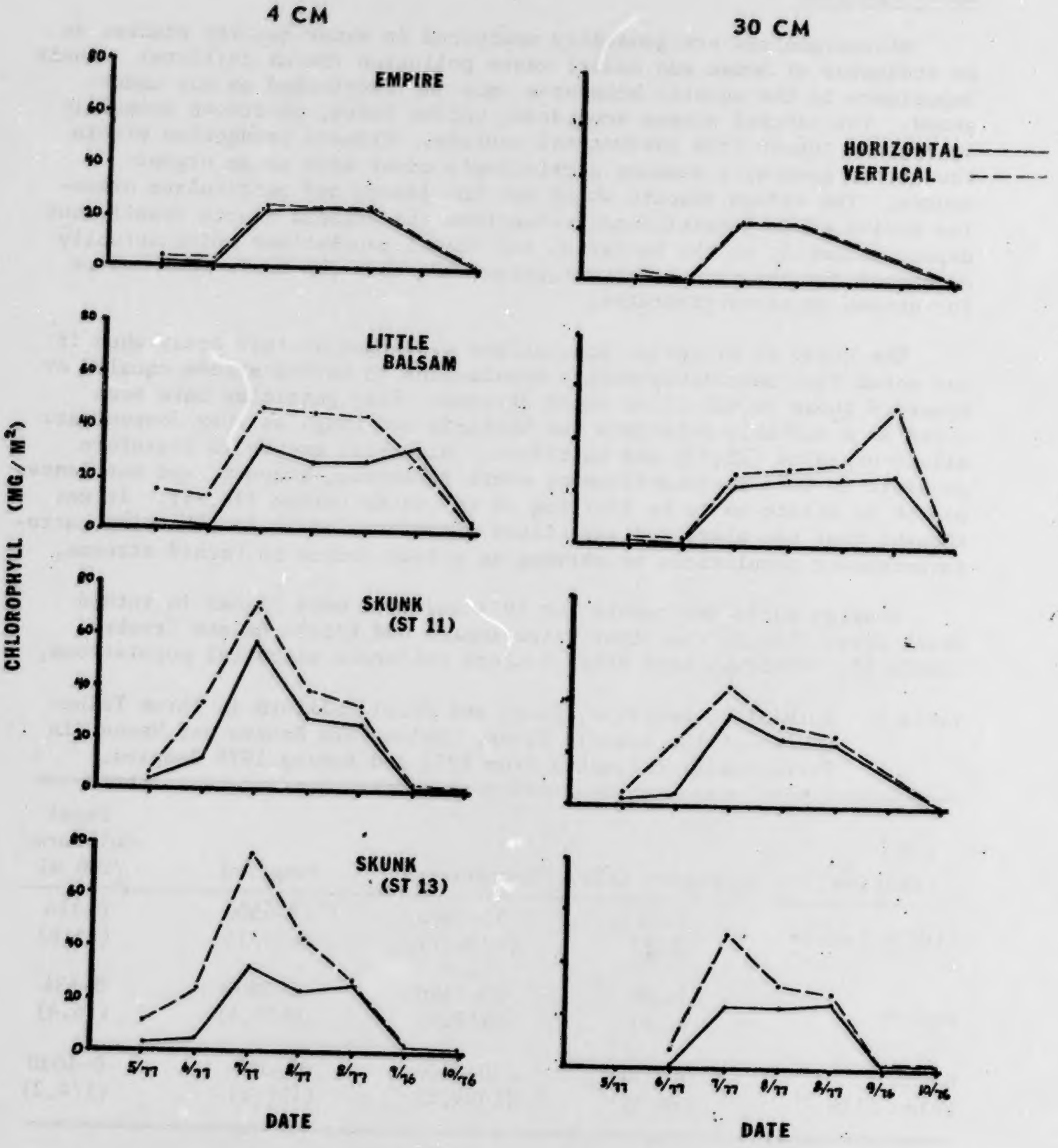

Figure 1. Mg/m^2 of chlorophyll a on glass slides at 4 and 30 cm and in Horizontal and Vertical Orientations in Empire, Little Balsam and Skunk Creeks.

below Elim Creek has slightly depressed levels. Water temperature and incident light (Empire Creek has the lowest mean annual temperature and densest tree canopy) have greater effects on production than the turbidity and sedimentation encountered in this study.

Microorganisms

Microorganisms are generally monitored in water quality studies as an indicator of human and animal waste pollution (fecal coliform). Their importance to the aquatic ecosystem may be overlooked or not understood. The natural stream ecosystem, unlike lakes, is driven primarily by organic inputs from terrestrial sources. Primary production within the stream generally assumes a relatively minor role as an organic source. The stream insects which eat the leaves and particulate organics derive minimal nutritional value from the organic source itself, but depend primarily on the bacterial and fungal populations which actually decompose the organics. Microorganisms are thus the basic food source for stream macroinvertebrates.

The study of microbial populations was begun in this study when it was noted that macroinvertebrate populations in turbid stream equaled or exceeded those in the clear water streams. Clay particles have been cited as a suitable substrate for bacteria and fungi as they concentrate dilute organics (22,23) and nutrients. Microbial growth is therefore possible in this microenvironment where substrate, enzymes, and nutrients may be so dilute as to be limiting in the water column (24,25). It was thought that the clays and associated microfauna could be enhancing macroinvertebrate populations by serving as a food source in turbid streams.

Average bacterial counts for 1977 and 1978 were higher in turbid Skunk Creek than in the clear water Empire and Little Balsam Creeks (Table 5). Although many other factors influence microbial populations, this indicated a positive trend with turbidity. If the bacterial fauna was closely associated with the clay particles in turbid samples, actual populations could have been higher as the membrane filter technique used for enumeration would allow only one colony count per clay particle,

Table 5. Turbidity, Bacteria, Fungi and Fecal Coliform in Three Tributaries of the Nemadji River. Values are Ranges and Means (In Parenthesis) Estimated from 1977 and Spring 1978 Samples.

Station	Turbidity (FTU)	Bacteria/ml	Fungi/ml	Fecal Coliform/ 100 ml
Little Balsam	3-25 (5.9)	90-3200 (1076.7)	13-6500 (689.2)	0-114 (15.6)
Empire	2-25 (4.9)	90-1400 (819.3)	5-5900 (650.4)	0-134 (16.4)
Skunk Below Elim	10-220 (50.3)	230-8000 (1499.4)	33-325 (157.6)	0-1030 (174.2)

even if several bacteria were present. Fungal populations exhibited opposite trends as counts were generally lower in Skunk Creek.

The trends which appear for between site comparisons of fungal and bacterial counts are not apparent for within stream counts. No consistent correlations were found as turbidity increased at each site. Factors associated with rainfall and increasing turbidities (dilution, nutrient input, terrestrial microbes) cause greatly fluctuating populations and obscure relationships.

Fecal coliform counts were higher in Skunk Creek than in the other two sites (Table 5), but this site is in an area with more livestock. Fecal coliform counts are associated primarily with human and barnyard wastes and are more indicative of point-source pollution. Relationships with red clay erosion are somewhat obscure.

Potential trends of higher bacterial populations appear possible, but present techniques reveal no startling increases. Difficulties in accurate enumeration may mask more significant differences, however. The fact that clay particles may concentrate bacteria and fungi is potentially beneficial to macroinvertebrates as they are more readily available to the large number of insects which feed by filtering particles from the water column.

Macroinvertebrates

The effect of heavy sedimentation on stream macroinvertebrates has been shown by some authors to affect the numbers and biomass of organisms with very little associated change in species composition (17,18). Herbert *et al.* (18) found the bottom fauna to be 3.3 times more numerous where heavy clay sediment was not polluting the stream. No changes in species composition were noted. Turbidity levels of the polluted stream in that study varied from 900-7500 ppm, a minimum of 6 times the high levels normally found in the Nemadji Basin. Other authors, including studies cited by Cordone and Kelly (15) and Chutter (26), found significant changes in the composition of the bottom fauna with increased siltation.

The effect of sedimentation on the benthic fauna seems to be manifested primarily through changes in the character of the stream substrate. Complete inundation of pools and riffles by silt and sand, as has occurred in several studies, would have obvious effects on faunal composition through formation of a monotypic environment. It is also a very unstable environment, unsuitable for trapping detritus and prone to be flushed away during floods. When a rocky stream substrate is not completely covered, reduction in the benthic population may occur through elimination of interstitial space. The preference (or greater population size) of insects has been found to be large rubble > medium rubble > gravel > bedrock > sand (27,28,29). Generally, the more interstitial space, the higher the preference for the substrate.

Rates of deposition in areas of the Nemadji River Basin where most of the erosional products are clay are not great enough to inundate any of the rocky substrate. The most dramatic effects of erosion are in reaches of the river where large quantities of sand are contributed to the bed load. The substrate in these areas is extremely unstable and harbors the lowest benthic populations in the system (Site 4, Figure 2).

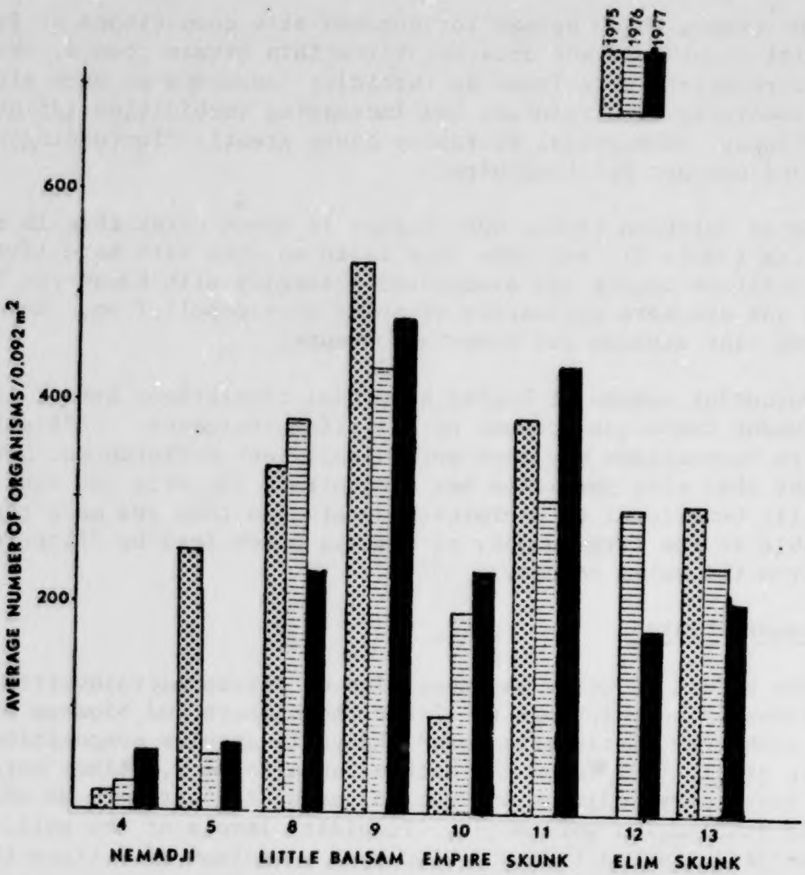

Figure 2. Average Number of Organisms in Surber Samples From Sites on the Nemadji River and Tributaries

Only the biting midges, Ceratopogonidae, seem to be adapted to this shifting sand. In more upstream areas of the Nemadji and in the tributaries where little sand is contributed to the bed load a pool-riffle continuum is formed with stable substrates and resultant increases in benthic populations.

The turbid tributaries with stable substrates support as large a benthic population as do those streams with minimal erosion and high water clarity (Figure 2). The lowest populations, in fact, occur in Empire Creek (with the exception of the Nemadji River sites with unstable substrate) which has one of the lowest mean annual turbidities and no clay in the watershed. Small gravel predominates in the riffle areas as opposed to rubble and large gravel at all other sites. The lack of the larger substrates is a major factor in reducing benthic populations. The highest average number of benthic organisms (Site 9 on Little Balsam Creek) is in an area with an extremely stable discharge and rubble in both the pools and riffles.

The total number of taxa (generic level) occurring at the various sites is also insensitive to clay sedimentation (Figure 3). Again, only the Nemadji River sites with unstable sand substrates demonstrate a significant decrease.

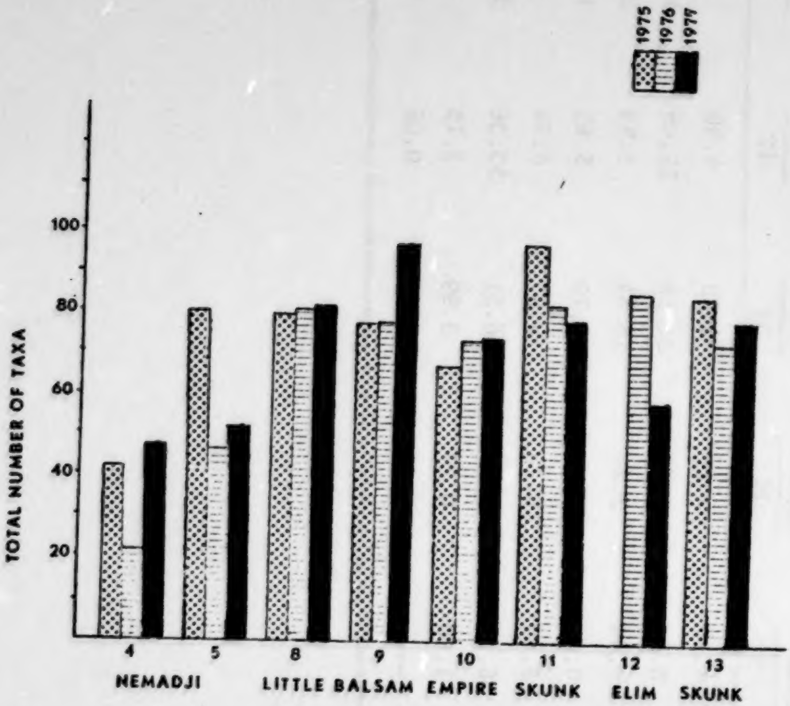

Figure 3. Total Number of Taxa in Surber Samples From Sites on the Nemadji River and Tributaries

With the lack of responsiveness in both total number of organisms and number of taxa, it is not surprising that species diversity does not change in relation to levels of turbidity or clay sedimentation (Figure 4). The differences which were formerly apparent in the Nemadji River sites in total numbers and number of taxa are, in fact, obscured. The sandy substrate is not an environment which limits survival in so much as it prevents occupation. No species dominates, resulting in the collection of many genera in fairly low numbers and a fairly high species diversity. Species diversity is thus a very poor index of the effects of turbidity and sedimentation under conditions encountered in this study.

The taxonomic composition of the turbid and clear water sites differed slightly, but no changes could be positively identified as a negative impact of silt and clay sedimentation. At the ordinal level, there is a distinct reduction in the number of Plecoptera (stoneflies) from the clear-water Little Balsam and Empire Creek sites to the relatively turbid sites in the Nemadji River and Skunk Creek (Table 6). This may not be related to turbidity or sedimentation, however, as stoneflies are extremely sensitive to high temperatures (30) and the higher average

Table 6. Percent Composition of Benthic Samples of Major Groups of Organisms for All Samples in 1975-1977. Chironomidae is not included with other Dipterans.

	Nemadji		Little Balsam		Empire	Skunk	Elim	Skunk
	4	5	8	9	10	11	12	13
Plecoptera	1.12	3.05	7.32	14.16	15.18	3.23	4.50	2.22
Ephemeroptera	7.96	16.20	8.98	8.77	6.09	21.18	22.68	11.82
Trichoptera	0.28	38.90	39.46	19.64	3.24	18.54	8.93	24.10
Coleoptera	0.50	4.23	0.62	0.32	0.13	15.70	5.65	16.27
Diptera	38.79	7.04	6.81	18.83	18.74	9.47	6.34	6.20
Chironomidae	47.70	27.75	31.54	36.73	55.79	26.51	53.36	34.45
Oligochaeta	3.25	2.70	5.07	1.00	0.27	3.99	2.15	3.17
Nematoda	0.02	0.03	0.02	---	0.04	0.08	0.06	0.16

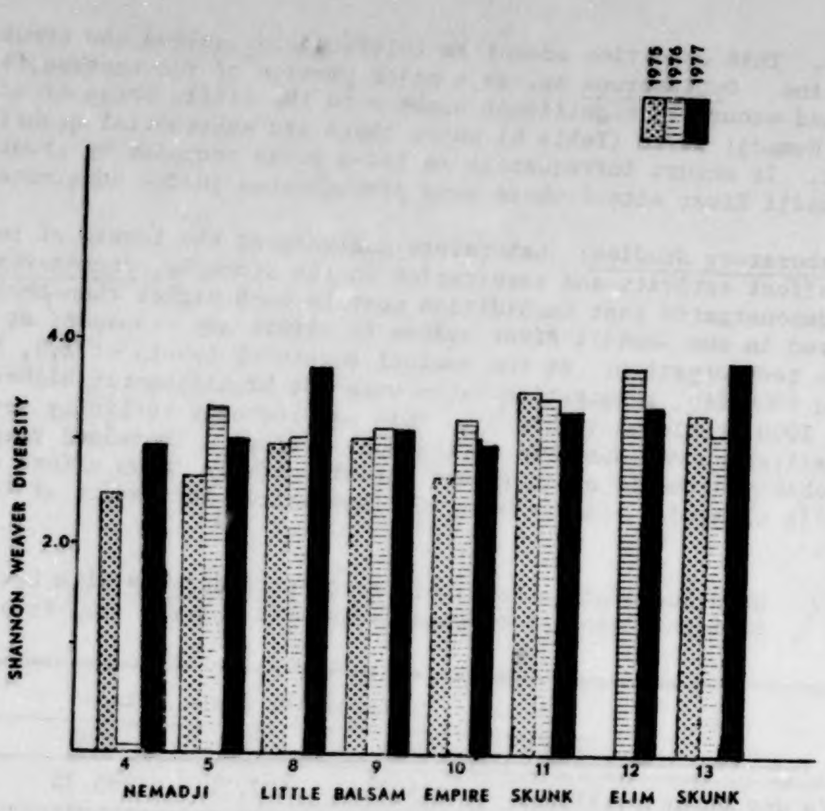

Figure 4. Shannon Weaver Diversity Indices for Benthic Samples From Sites on the Nemadji River and Tributaries.

temperatures in Skunk Creek could effect this change.

Oligochaetes are one of the most sensitive indicators of silt in the substrate. The largest numbers occurred in the lower reaches of the Little Balsam where small quantities of clay and silt are found in the predominantly sand substrate of the pools. The relative numbers of oligochaetes remained low at all times, but areas with no clays in the sediment had 1% or less in the benthos and areas with small to larger amounts of clay sediment generally had 2.5-5.0%.

The mayflies, generally considered one of the most sensitive orders of insects for pollution studies, had significantly greater populations in turbid Skunk Creek than in the clear-water tributaries. No genera seemed to be hindered by turbid or silty conditions, but silt-loving genera such as Caenis sp., Hexagenia sp., and Ephemera sp. increased significantly. The family Heptageniidae and Isonychia sp. also increased in numbers.

The beetle larvae, Optioservus sp., is perhaps the best indicator for levels of silt which are potentially detrimental to spawning success of the salmonids which require a free flow of water through the rocky riffles. Optioservus sp. (which represent most of the Coleoptera in Table 6) is found almost entirely in riffle areas and occurs in significant numbers only where there is silt in the interstitial spaces of the riffles. This condition cannot be tolerated for salmon and trout reproduction. Optioservus sp. is a major portion of the benthos in Skunk Creek and occurs in significant numbers in the riffle areas of site 5 on the Nemadji River (Table 6) where there are substantial quantities of silt. It occurs infrequently in those sites occupies by trout and the Nemadji River site 4 where sand predominates in the substrate.

Laboratory Studies: Laboratory analysis of the levels of turbidity which affect activity and respiration in the stonefly, Pteronarcys dorsata, demonstrated that turbidities must be much higher than those encountered in the Nemadji River system to elicit any response, at least for the test organism. At the nominal turbidity levels of 2,5, 100, 250, 500 and 1000 ftu, respiration rates were not significantly higher except at the 1000 ftu level (Table 7). This was the only turbidity level at which siltation was observed on the body surface. Increased respiration was probably a result of increased activity levels in an effort to keep the gills cleared. Similar behavior is elicited in insects at low oxygen levels.

Table 7. Mean Respiration Rates of Pteronarcys dorsata With Levels of Significance for Comparisons with Control (2.5 ftu).

	Turbidity Level (ftu)				
	2.5	100	250	500	1000
µl O_2/g dry wt/hr	338.95	275.71	407.21	295.35	709.41[a]

[a] Significant at .01.

Levels of activity at the nominal turbidities of 1.5, 25, 60, and 150 ftu were monitored at three discharges (250, 500 and 1000 ml/min). There were no significant trends at 1000 ml/min (P = .54). Activity increased with turbidity at 500 ml/min but was not significant at the 95% confidence level (P = .059). There was a significant increase in activity at 250 ml/min (P = .03). Activity did not increase appreciably until turbidities reached the highest level (150 ftu). Although this turbidity level does occur in the Nemadji River System, it is equaled or exceeded only during high water periods at which time current velocities are quite high.

Fish

The Nemadji River headwater streams are in both sandy and clay type soils. Those streams originating in the sandy reaches have good aquifers and are generally cold-water trout streams. Those in areas dominated by clays have very poor aquifers and receive most of their discharge from surface runoff. These streams will either not support trout or are very poor trout waters due to marginally high water temperatures and unstable discharges. Of the study streams, Empire and Little Balsam Creeks originate in sandy areas and are trout waters. Skunk and Elim Creeks and the main body of the Nemadji River originate or flow primarily through clay soils and do not support viable populations of cold-water fish.

Differences in discharge and temperature thus made interpretation of differences in fish populations among the study streams difficult. The Nemadji River and turbid tributaries support fish populations dominated by minnows but no major predators. Three trout were found in three years of sampling Skunk Creek. A few migrant spawning brown trout and steelhead and a rare northern pike or rock bass composed the predator population in the Nemadji River with the exception of large population of walleye during late spring and early summer in deeper reaches of the river close to Lake Superior. This lack of predators in the turbid streams is probably related more to channel form, temperature, and discharge than turbidity.

Lake trout have been shown to avoid turbid waters in Lake Superior (4) and it is likely that the waiting-watching-darting which typifies feeding behavior in stream-dwelling trout is hindered by turbid water. However, low discharges and marginal temperatures which characterize turbid streams in the Nemadji drainage are probably as inhibitory to trout habitation as turbidity.

The reliance of trout on water discharge as a dimension of space (they allow the food to come to them instead of actively seeking) make them one of the best adapted of the predatory game fish for small streams or shallow rivers where little foraging space is available. Streams the size of Little Balsam, Empire and Skunk Creeks would not provide adequate space for any other game species. The middle reaches of the Nemadji River, with widths exceeding 20 meters, are typified by shallow pools and no undercut banks. The lack of living space for large fish other than trout, water temperatures which are not tolerated by trout, and lack of winter refuge when ice forms on this shallow river combine to provide a habitat which is suitable only for year-round residence of minnows and other small species and as a seasonal spawning ground for some Lake Superior fish.

The major importance of the Nemadji River to fish is as a spawning ground. Turbidity in the lower reaches and mouths of rivers has been cited as a potential deterrent to spawning runs of trout (21). Significant spawning runs of steelhead occur in the Nemadji River during its most turbid periods, however, as the trout traverse up to 100 km of river to spawn in headwater streams where clays are absent.

Fish reproduction in most of the Nemadji River proper is limited to those species which do not bury their eggs. The salmonids, which bury their eggs, require fairly high rates of water flow through a rocky substrate for selection as a spawning site (10,11), survival of eggs, and emergency of fry (12,13,14). Natural rates of siltation in the Nemadji River are much too high for successful reproduction of these fish, even with major erosion control efforts.

The warm and coolwater species which migrate from Lake Superior to utilize area streams and rivers for spawning include burbot (Lota lota), walleye (Stizostedion vitreum vitreum), rainbow smelt (Osmerus mordax), and suckers (both Catostomus sp. and Moxostoma sp.). All of these fish broadcast their eggs over rocky areas after which they settle and adhere to the substrate or find refuge in the interstitial spaces. Both field monitoring and laboratory bioassays were conducted to assess spawning success of these species (except burbot) in the Nemadji River System and the effect of turbidity and siltation on egg survival.

All species mentioned above except the walleye utilize the Nemadji River for spawning. Walleye have not been observed to spawn in the Nemadji River, although they do spawn in the adjacent Pokegama River which has similar levels of turbidity and siltation. It therefore seems likely that factors other than turbidity discourage its use. Spawning success of the major runs of smelt, longnose and white suckers, and silver and shorthead redhorse was monitored using daily drift net samples during the periods of hatch. All of these species drift passively back to the harbor and Lake Superior after hatching, enabling rough estimates of total hatch when stream discharge and drift densities are known.

Smelt and suckers (all four species) hatched successfully in the Nemadji River in both 1976 and 1977. Larval smelt production in 1976 was estimated at just under 20,000,000. The major portion of the smelt hatch was missed in 1977, but the tail of the curve indicated similar trends. Sucker production in 1977 was estimated in excess of 23,000,000. Estimates in 1976 were not possible as fry were concentrated at the surface. Up to 2000 fry were captured in 15 minutes in the net with a mouth opening of .04 m^2, however. The only other species of fry captured is unidentified at present, but is probably a minnow. Numerical estimates of the unknown species were 590,000 and 1,900,000 in 1976 and 1977 respectively. Although some fry production may occur in clearwater tributaries, the collection of viable eggs and emergent fry in the Nemadji River indicate that most production occurs within the turbid waters.

Laboratory bioassays on egg survival of smelt and walleye indicate some reduction in walleye egg survival at turbidities above 10 ftu (Figure 5). Survival exceeded 50% of control up to 50 ftu, however, which is representative of actual stream turbidity values. Results of smelt egg survival bioassays were not consistent between 1976 and 1977 as no reduction in survival occurred with turbidity in 1976, but survival decreased with an increase in turbidity in 1977 (Figure 5). Survival was not reduced to zero at any turbidity level tested.

Survival in the bioassays was probably much lower than would occur at similar levels of turbidity in a natural system. Although the bioassays were conducted in a flowing water system, sedimentation on the eggs was much higher than has been seem to occur at high turbidities in the river. This is a result of more laminar flow in the test chambers and lower velocities than would occur at high turbidities in the river.

It appears that egg survival and hatching success may be slightly impaired in species of fish which could spawn in the Nemadji River, but this effect does not seem to be critical in light of the reproductive success of smelt and suckers. Erosion which caused severe silt deposition over spawning sites would be harmful, but the velocities which occur in the system under the conditions of high turbidity are sufficient to maintain most of the fine sediments in suspension until they reach the slower deeper areas of the river where these species do not spawn. The only tributaries where spawning success could be significantly reduced are the cold water streams which are used for salmonid reproduction. Slightly aggravated erosion would be enough to cause sufficient sedimentation to impair intragravel water flow.

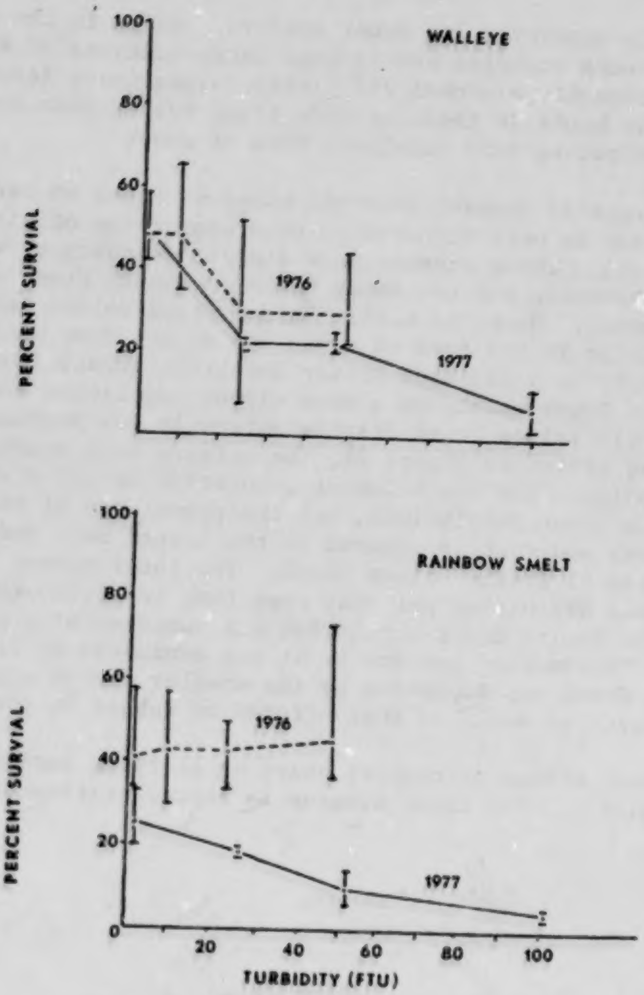

Figure 5. Mean and Range of Survival of Walleye and Rainbow Smelt Eggs Incubated at Various Turbidities (FTU). Eggs Incubated During 1976 Were on Gravel and Sand; Those Incubated During 1977 Were on Gravel Only. During Both Years Two Current Velocities Were Used But No Significant Differences Were Found. Mean Water Temperatures Were 10.0 and 8.3 C for Smelt Egg Incubation and 10.3 and 8.9 C for Walleye Egg Incubation for 1976 and 1977, Respectively.

The single most important factor regulating fish population size within the Nemadji River System is channel form. The species which inhabit different portions of the system are dictated primarily by water temperature and discharge, but physical characteristics of the channels which provide cover and depth are uniformly beneficial to all of these populations. Maximum standing crops and production for both warm and cold water fish are inevitably associated with habitat diversity (see reviews by 31,32). One of the most important components of habitat involved in the concept of "suitable living space" for fish is cover, which might be provided by water depth, overhanging banks, submerged rocks, logs, and other "snags". Suitable cover has been demonstrated to be the primary factor regulating population size of brown trout (33) and is similarly important for other species. Cover in the form of roots along channel banks harbored the largest concentrations of fish in both Skunk Creek (primarily minnows) and Little Balsam Creek (trout). The toes of the clay banks in these streams slump rather than form undercut banks, eliminating this excellent form of cover.

The influence of channel form and undercut banks on carrying capacity of the stream is well illustrated by a comparison of Little Balsam and Empire Creeks. These streams have similar discharges, water quality, and water temperatures but the sandy banks in Empire Creek are steep-sided and undercut. Banks in Little Balsam Creek seldom undercut and cover is primarily in the form of roots and logs. Many authors have cited food supply as a limiting factor for trout populations (34,35,36). However, Empire Creek maintains a much higher population and biomass of trout than Little Balsam Creek despite extremely low populations of macroinvertebrates (refer to Figure 2), the primary food source for stream dwelling salmonids. The small insect population is not a result of cropping by the trout populations, but the prevelance of small and consolidated gravel and rock as opposed to the larger rock and rubble in the riffle areas of Little Balsam Creek. The total number of fish in Empire Creek was 42% higher per unit area than in Little Balsam Creek. In addition the Empire Creek population was composed of a much greater percentage of "desirable" species as it was dominated by brook trout and Little Balsam Creek was dominated by the smaller minnow species which can utilize cover as small as that offered by rubble in the riffle areas.

The general effect of channel shape on carrying capacity is illustrated in Figure 6. The first diagram is representative of channel form

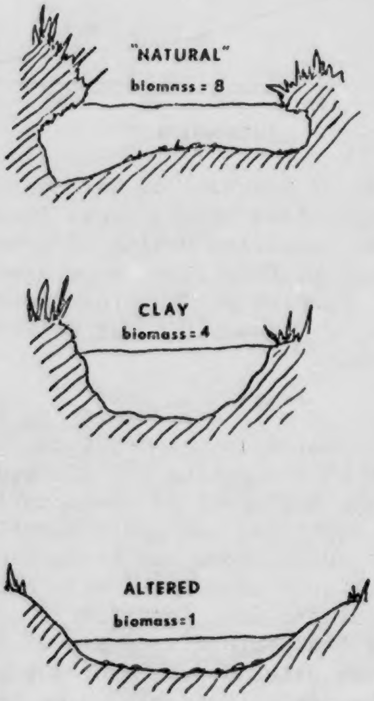

Figure 6. Typical Channel Forms and Approximate Fish Biomasses (modified from 37).

found in Empire Creek, the second the form in many of the areas with clay slumpage, and the third is typical of a channelized stream. Biomass estimates are representative of expected population sizes of all sizes and species of fish (modified from 37). "Catchable" fish would decline even more drastically as the channels become less and less suitable for large fish.

Cover is one of the most important factors in maintenance of large populations for all species complexes in the Nemadji River System. Cover limitations as a result of bank slumpage is the major red clay associated feature affecting aquatic life. Practices commonly associated with "river cleanup" such as stump and snag removal should be discouraged as it provides the best cover available in these streams. Other practices which slow the rate of toe erosion of the banks may be beneficial in maintaining steeper banks which maintain water depth and are a form of cover.

CONCLUSION

The potentially severe effects of erosion and sedimentation on aquatic life should not be underestimated. Adequate documentation exists to identify the severe short and long term effects of soil mismanagement on all levels of the aquatic flora and fauna (reviews by 15, 38). It should not be assumed, however, that relatively low levels of erosion are detrimental to all aquatic systems. Our experience in turbid areas of Lake Superior and the Nemadji River System, which is turbid throughout the year due to erosion of unconsolidated glacial lake deposits, indicate that the direct physical effects of low level turbidity and sedimentation are minimal. More important effects within these systems are a result of behavioral changes, many of which could be considered beneficial to the indigenous species.

Problems attributed to red clay turbidity have included replacement of desirable by less desirable fish species, discouragement of spawning runs, decreased oxygen levels, increased nutrient levels, and general statements of "adverse effects on biological life processes." None of these statements have proven true through our studies in the Nemadji River System. Accusations such as "turbid streams are unattractive and difficult to fish" (39) are harder to refute, and may stand as some of the more damning evidence against moderate turbidities in cool and warm water streams. More realistic problems include sedimentation necessitating dredging in river mouths and clogged water intakes, but these are not biological and have not been considered within the scope of this paper.

The only conclusive detrimental biological effects of relatively low levels of sedimentation are the adverse impacts on salmonid reproduction. These have not been addressed through our studies, but adequate documentation exists in the literature to identify the sensitivity of salmonid eggs in redds, which require a flow of water through the gravel, to sedimentation (12,13,14). There is also evidence that salmonids will avoid turbid waters, both in lakes (4) and in streams. This seems to be a result of their reliance on sight feeding on drifting macroinvertebrates, at least in lotic systems. Reproductive success in the Nemadji River System, much of which is too warm for salmonids, does not seem to be greatly affected by existing turbidities judging from both documented reproductive success of smelt and suckers and egg survival bioassays on these species and walleye.

Existing levels of streambank erosion in this river system should therefore not be assumed to have widespread detrimental effects on the aquatic biota. The watershed is relatively unperturbed at this time and erosion control practices cannot be expected to have a significant positive effect on aquatic resources. Careful management along roadside right-of-ways and curbing extensive cattle grazing of streambanks will help to prevent widespread degradation of the system, but the most positive results of the present erosion control engineering studies will probably be the development of techniques to prevent slippage of hillsides and losses of roads and personal property.

SUMMARY

1. Red clay does not contribute significant quantities of nutrients to Lake Superior but may serve to transport nutrients contributed from point sources.

2. Oxygen levels are not significantly affected by red clay or associated organics.

3. Primary production does not appear to be significantly affected by turbidity within the range of depths at which most production occurs in these relatively shallow streams.

4. Bacteria exhibit no definite trends with turbidity within sites, but do seem to have higher counts in turbid than in non-turbid sites. Fungal counts exhibit opposite trends. Bacterial and fungal populations are generally beneficial to the aquatic system as they are the primary food source for many of the macroinvertebrates.

5. Number of macroinvertebrates per unit area, total number of taxa, diversity, and biomass are not significantly affected by clay turbidity and siltation within the Nemadji River System.

6. Substrate size had much greater effects on macroinvertebrates than turbidity and sedimentation. Only where sand was the primary product were significant detrimental effects of erosion identified.

7. All genera of insects which occurred in clear streams also occurred in turbid streams. Certain silt-loving insects, especially certain mayflies and beetle larvae, were found only in the turbid streams.

8. Laboratory monitoring of activity and respiration of the stonefly Pteronarcys dorsata demonstrated no significant effects at turbidity levels normally encountered in the Nemadji River System.

9. Fish populations were not demonstrated to change as a result of turbid conditions because of water temperature and discharge differences between turbid and clear water sites. All species complexes benefitted by increased cover which is harder to maintain in turbid streams due to increased tendencies for slippage at toes of the clay banks.

10. Walleye in the lower Nemadji River, the Duluth-Superior Harbor, and Lake Superior benefit from red clay turbidity as it enables them to inhabit the shallow, more productive waters.

11. Rainbow smelt and four species of suckers successfully reproduce in the turbid areas of the Nemadji River System.

12. Egg survival bioassays with walleye and rainbow smelt indicated decreased survival at turbidities over 10 ftu. Survival was at least half of control at turbidities prevalent in the Nemadji River. Levels of sedimentation in the bioassay were much higher than in the natural system, probably resulting in higher egg mortality than would naturally occur.

13. Channel form and available cover are the primary factors affecting fish population size for all species complexes in the Nemadji River System.

RECOMMENDATIONS

The major effect of the red clays on the aquatic biota are associated with characteristics of the soils which affect channel form. Undercut banks and other channel characteristics which provide cover have major impacts on all types of fish populations. The major recommendations which can be identified through this study are therefore related to preservation of the toes of slopes to maintain undercut banks (though they seldom occur in these soils), steep sided channels, and pool depth, all of which provide forms of cover. Recommendations are as follows:

1. Retaining peak discharges after rainfall should slow erosion rates and preserve streambanks. Floodwater retaining structures may be effective, but barriers in streams and substitution of a lake for a stream environment is potentially disruptive and self-defeating. More desirable controls would be retention by adequate vegetative cover and leaf litter and land use practices which minimize runoff.

2. Vegetation which stabilizes streambanks may allow undercutting, steeper banks, and deeper pools. Woody root systems provide excellent cover for forage fish and harbored major fish concentrations in study streams.

3. Removal of stumps and other snags is definitely detrimental to fish populations. The pools eroded around such structures coupled with the associated cover provide some of the best habitat in these turbid streams. The erosion is insignificant compared to benefits to fish populations.

4. The grazing of cattle and other lifestock on streambanks breaks down slopes, eliminates cover, potentially decreases stream depth, and generally disrupts the stream biota. Livestock exclusion is recommended.

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LAND MANAGEMENT PRACTICES FOR THE RED CLAY PROJECT

by

U.S.D.A. Soil Conservation Service*

On July 10, 1975, the U.S.D.A. Soil Conservation Service (SCS) entered into a 3.5-year cooperative agreement with the Douglas County Soil and Water Conservation District, the designated fiscal agent of the Red Clay project. The Service agreed to provide technical assistance to implement an accelerated erosion and sediment control program in the Western Lake Superior Basin (Red Clay project).

Under this program, demonstration erosion and sediment control measures were planned and installed by the soil and water conservation districts (SWCD's) of Ashland, Bayfield, Douglas, and Iron counties, Wisconsin, and Carlton County, Minnesota, with the SCS providing technical assistance.

This work was in addition to the ongoing district programs of the five counties. One of the objectives was that the implementation of a demonstration program would provide the SCS, Environmental Protection Agency (EPA), and SWCD's with a technical evaluation of water quality changes resulting from the installation of erosion and sediment control measures. The knowledge gained is to be used on a regional and statewide basis for assistance in directing of other SWCD programs.

The following was provided by the SCS:

1. A soil survey and interim report for the Nemadji River and Fish Creek basins.
2. Land use analysis and soil loss inventory for specified study areas.
3. Conservation plans for the purpose of developing cost-sharing contracts for the installation of conservation systems in the five SWCD's.
4. Construction inspection for structural measures installed by local contract.
5. Technical assistance in preparing an operations manual.
6. Project evaluation.

Planned activities in the Red Clay project area where SCS technical assistance was provided:

Bayfield County SWCD - Upland Conservation Treatment
Streambank and Slide Stabilization
Soil Survey (Fish Creek Basin)

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*SCS, Minnesota and Wisconsin

Carlton County SWCD - Upland Conservation Treatment
Streambank and Slide Stabilization
Sediment Retention Structures

Douglas County SWCD - Upland Conservation Treatment
Streambank and Slide Stabilization
Roadside Treatment
Soil Survey (Nemadji Basin)

Iron County SWCD - Sediment Retention Structure

OVERVIEW

Lacustrine clay soils or "red clays" dominate the three study areas. Significant portions of each area also contain glacial outwash sands. It is the red clay areas that are generally associated with nonpoint source pollution problems.

The study area sizes are within watershed boundaries and are as follows:

Pine Creek - Bayfield County - 15.7 sq. miles
(10,048 acres)

Skunk Creek - Carlton County - 10.7 sq. miles
(6,848 acres)

Little Balsam Creek - Douglas County - 5.4 sq. miles
(3,450 acres)

Table 1. Land Use Percentages

Land Use	Study Area 3		
	Pine Creek	Skunk Creek	Little Balsam Creek
	(Percent)	(Percent)	(Percent)
Woodland	59	73	81
Hayland	21		7
Pasture	12	7	3
Wildlife	2		3
Idle Land	3		6
Cropland	3	16	
Other Uses		4	

Soil loss evaluations in the study areas were conducted using the Universal Soil Loss Equation (USLE). It was applied to all privately owned lands in the study areas. Landowners were encouraged to participate in field investigations and were provided copies of the evaluations.

The Universal Soil Loss Equation was only used as an indicator of soil loss and as an indication of the effectiveness of land treatment. It cannot address the problem of sediment transport.

The majority of the soil loss from the three study areas is from critical areas. These areas are steep (10-45%) slopes that are adjacent to streams or drainageways. They are in either grass or woodland and are either pastured or found in natural condition.

In the Pine Creek study area the annual allowable estimated soil loss ranges from 3-5 tons per acre. The USLE was applied to 6,576 acres. Approximately 10%, or 654 acres, had an annual estimated soil loss of 18.6 tons per acre. The remaining 90% averaged .15 tons. The critical areas were steep pastured woodlands and steep, over-grazed pasture areas. In both cases vegetative cover conditions were poor.

The most intensive land use is in the Skunk Creek study area. Most of the area was found to be within the allowable soil loss (4 tons per acre) except for steep, over-grazed slopes adjacent to streams. The average annual estimated soil loss for this study area is slightly less than 1.0 ton per acre.

In the Little Balsam study area the USLE was applied to 1,620 acres of private land, 80 acres of Douglas County-owned woodland, and 258 acres of the Village of Patzau.

The average annual estimated soil loss for the Little Balsam study area is .55 tons per acre. Hayland averages .3 tons, idle land .1 ton, pasture .8 tons, and woodlands .6 tons per acre.

The Little Balsam study area is as close to a natural state as can be found in the Red Clay project area. Land use intensity is low, and the area is in good vegetative cover. The major sediment sources are critical areas such as raw streambanks, landslides adjacent to streams and steep woodland areas adjacent to streams.

Land ownership in the Pine Creek study area is 65% private and 35% county and Federal (all managed as woodland). There are 76 private landowners. Twenty-seven are absentee and 49 are resident. Five landowners classify themselves as full-time farmers, and 13 more as part-time. Thirty-five landowners (71%) were over 55 years of age.

Fifty private landowners in the Skunk Creek study control 80% of the land. There are five absentee owners. Ten part-time beef and 10 dairy operations are located here. The remaining land units provide primarily woodland recreation with six units renting hayland to neighboring farmers. The average landowner age in the watershed is 50.

Land ownership in the Little Balsam study area is 53% local government and 47% private. There are 13 absentee and 16 resident landowners. Beef and hay production are the principle farm enterprises. In January 1978 there were approximately 40 beef cattle or other livestock in the study area. The majority of landowners are at least 50 years old.

PROBLEMS & SOLUTIONS

Roadside Erosion

Roadside erosion is common on roads that are not properly designed or vegetated and on roadsides where "maintenance" activities destroy existing vegetative cover.

The installation and maintenance of properly designed road ditches and waterways with the establishment of vegetative cover on all road ditches and right-of-ways would reduce soil loss and subsequent sediment pollution from these sites.

Sliding Streambanks

Landslides are a natural occurring phenomenon in the Red Clay areas. They can produce high volumes of sediment. Several structural measures were planned and installed in an effort to control this problem.

Streambank stabilization utilizing rock rip rap and drainage was installed at one site on Little Balsam Creek at a construction cost of $160 per lineal foot.

Another site used rock filled concrete log cribs to stabilize the slope and counterweight the slide. The area was also drained. The construction cost was $825 per lineal foot.

Evaluation of these structural methods is not yet complete and effectiveness is not yet known. In a 2,000-foot section of Little Balsam Creek eight slide and streambank sites were identified. This indicates the extent of the problem and cost of total protection.

A streambank and slide stabilization measure planned in Bayfield County was not installed by the local unit of government because of high cost ($90,000).

In Carlton County construction to stabilize a streambank and roadside erosion site was completed in June of 1977. This work is currently being evaluated for effectiveness. The construction cost is $232,849.

Sediment & Flood Storage Measures

Sediment storage measures were initially planned in the Little Balsam study area and Iron County but were dropped when further investigation indicated that there were no feasible sites.

Sediment storage and floodwater retarding structures are currently under construction in Carlton County, Minnesota. The resulting reduced floodwater flows will help protect streambanks. Storing sediment and allowing it to settle out in storage basins will reduce the sediment load carried into the stream. One of the structures has an estimated cost of $218,000 and the other $191,000.

Upland Conservation Treatment Systems

Treatment of upland areas was based on working with private landowners on a voluntary basis through the local soil and water conservation district. Landowners became district cooperators and were assisted in developing conservation plans of operation.

The conservation plans served as the basis for the Red Clay long-term agreements, which are contracts between the landowners and the district, to provide cost sharing for the installation of upland conservation practices.

Each district administered its own program. Cost-shared practices and the rates were determined by each district. (See appendix A.) Priority practices treating critical sediment producing areas were assigned higher rates of cost sharing. This provided extra installation incentive.

Cost-sharing (80-100%) was authorized for conservation plan elements which controlled livestock by providing fencing, alternative watering facilities, livestock stream crossings, and stock trails.

Cost sharing was also authorized for a wide range of complementing conservation plan elements that are needed on the uplands. These practices include such as pasture and hayland planting and management, diversions, grassed waterways, drainage ditches, and tree planting. These plan elements maintained non-critical portions of the land unit at low levels of soil loss.

The Red Clay project long-term agreement was used by nine landowners in Pine Creek, 26 in Skunk Creek, and four in Little Balsam Creek. It is estimated that 90% of the contracted practices in the Pine and Skunk Creek study areas will be installed by July of 1978.

The average estimated cost per long-term agreement was $12,447 in Pine Creek, $9,000 in Skunk Creek, and $6,280 in Little Balsam Creek. Estimated per acre treatment costs average $70 per acre in Pine Creek, $55 per acre in Skunk Creek, and $98.50 per acre in Little Balsam Creek.

In the Pine Creek sutdy area approximately 50% of the total estimated cost per long-term agreement was allocated to provide treatment on high sediment-producing critical areas. The remaining 50% went to install complimenting conservation plan elements on the remaining acreage in the unit.

The continued effectiveness of the practices installed will depend on landowner maintenance.

BEST MANAGEMENT PRACTICES

Practices found to be most effective in the Red Clay project area were compiled from best management practices (BMP's) as determined in each study area. The following is a list of those practices:

Practice	Study Area
1. Maintenance of vegetative cover.	Pine, Skunk, Little Balsam
2. Livestock exclusion from critical areas (with fencing or management).	Pine, Skunk, Little Balsam
3. Alternate watering facilities.	Pine, Skunk, Little Balsam
4. Stock trails and walkways.	Pine, Skunk, Little Balsam
5. Livestock stream crossings.	Pine, Skunk, Little Balsam
6. Critical area seeding.	Pine, Skunk, Little Balsam
7. Grassed waterways.	Pine
8. Animal waste management systems.	Pine
9. Sediment traps.	Skunk

Maintenance or rapid reestablishment of vegetative cover is the key to low levels of nonpoint sediment pollution in the Red Clay areas. Policies and activities which provide for this vegetative protection will be best management practices.

APPENDIX A

DEFINITIONS OF LAND TREATMENT PRACTICES

1. Access Road is constructed as part of a conservation plan to provide needed access to farms, fields, conservation systems, structures, and recreation areas. The estimated cost includes clearing, earthwork, gravel surfacing, and seeding.

2. Agricultural Waste Management Systems is a planned system to contain and manage liquid and solid livestock wastes with disposal in a manner which does not degrade air, soil, or water resources. The cost is an average typical cost of those recently constructed.

3. Brush Management is management of brush stands to restore plant communities and specific needs of the landusers. The cost includes both chemical and mechanical brush control.

4. Conservation Cropping System is growing crops is combination with needed cultural and management measures. Cropping systems include rotations that contain grasses and legumes as well as rotations in which the desired benefits are achieved without the use of such crops. The cost includes the landuser's cost of establishing and maintaining contour strips, rotations, etc.

5. Critical Area Planting is stabilizing sediment-producing and severely eroded areas by establishing vegetative cover. This includes woody plants such as trees, shrubs or vines, and adapted grasses or legumes established by seeding or sodding to provide long-term ground cover, (does not include tree planting mainly for the production of wood products). The acreage of this item does not include roadside seeding needed and seeding as part of other conservation measures.

6. Crop Residue Management is using plant residues to protect cultivated fields during critical erosion periods. The cost is indicative of the added expense in converting to mulch tillage practices.

7. Diversion is a channel with a supporting ridge on the lower side constructued across the slope for the purpose of diverting water to areas where it can be disposed of safely. The cost includes earthwork and seeding.

8. Drainage Field Ditch is a graded ditch for collecting excess water within a field. It does not include grassed waterway or outlet. The quantity of this item is intended for application on the cropland.

9. Farmstead and Feedlot Windbreak is a belt of trees or shrubs established next to a farmstead or feedlot. The cost is for tree planting and materials.

10. Fencing is enclosing or dividing an area of land with a permanent structure that acts as a barrier to livestock or people. The quantity shown in the table is that needed for livestock exclusion from gullies and steep slopes. The cost is for material and labor.

11. Field Windbreak is a belt of trees or shurbs established next to a farmstead or feedlot. The cost is for tree planting and materials.

12. Floodwater Retarding Structure is a single-purpose structure providing for temporary storage of floodwater and for its controlled release. This structure is designed to trap sediment also, though not considered a purpose. The cost is the estimated construction cost for sites indicated on the work map.

13. Grade Stabilization Structure is built to stabilize the grade or to control head cutting in natural or artificial channels. (Does not include stream channel improvement, streambank protection, diversions, or structures for water control.) The higher cost is representative for construction of a low head, crib-type structures located in the stream channel to control gradient. The lower cost is representative for construction of high head, pipe drop-type structures for small watersheds.

14. Grassed Waterway is a natural or constructed waterway or outlet, shaped and graded, with vegetation established to safely dispose of runoff from a field, diversion, terrace, or other structure. The cost includes earth work and seeding.

15. Land Adequately Treated is using land within its capability on which the conservation practices that are essential to its protection and planned improvement have been applied.

16. Land Smoothing is removing irregularities on cropland surfaces by use of special equipment.

17. Livestock Exclusion refers to areas where grazing is prevented by fencing out livestock. The cost for doing such is the amount shown for fencing.

18. Pasture and Hayland Management is proper treatment and use of pastureland or hayland. The cost includes mowing and fertilization.

19. Pasture and Hayland Planting is establishing long-term stands of adapted species of perennial, biennial, or reseeding forage plants. (Includes pasture and hayland renovation, does not include grassed waterway or outlet on cropland.)

20. Recreation Area Improvement is establishing grasses, legumes, shrubs, trees, or other plants or selectively reducing stand density to improve an area for recreation. The construction cost is included in other practices.

21. Stock Trails, Walkway, or Watering Facility is a trail, walkway, or watering facility provided to improve access to water for livestock when fencing is used to exclude livestock from prior watering areas.

22. Stream Channel Protection and Slope Stabilization includes all those structural measures designed to control or reduce the amount of streambank erosion and stream sideslope failure (clay sides).

23. Stripcropping is the growing of crops in a systematic arrangement of strips or bands on the contour to reduce erosion. The cost includes the landuser's cost of establishing and maintaining strips.

24. Subsurface Drainage is a conduit installed beneath the ground surface which collects and/or conveys drainage water. The cost includes installation and material.

25. Tree Planting is the planting of tree seedlings or cuttings. Costs include materials and planting.

26. Woodland Improvement is removing unmerchantable or undesirable tree species, shrubs, or vines.

27. Woodland Site Preparation is treating areas to encourage natural seeding of desirable trees or to permit reforestation by planting or direct seeding.

MULTIPLE AGENCY MANAGEMENT
FOR
NONPOINT SOURCE POLLUTION CONTROL

by

Stephen C. Andrews*

The Red Clay Project is a joint effort of the SWCD's of five counties in two states. The Executive Committee of the Project is made up of a representative from each SWCD, with the Chairman from the Douglas County SWCD, the fiscal agent for the grant. The Executive Committee is responsible for Project affairs. Early in the Project the fiscal agent delegated authority to the individual SWCD's for program maintenance, local budgetary decisions, and other matters. This allowed the SWCD's to manage the Project in their areas consistent with their ongoing programs and policies. The only real management problem encountered in respect to this arrangement is that not all of the SWCD's held meetings on a consistent schedule, which, in several cases, prevented the Executive Committee from making timely decisions at its monthly meetings.

From a management standpoint, the consortium appears to be a workable system, at least as far as a research and demonstration project is concerned. It should be noted that this Project was conducted on a voluntary basis, with priorities and budgets based on a local government or landowners ability to provide necessary services; in-kind contributions; and matching dollars. Thus, we did not have SWCD's competing for priorities established because of limited funds. In addition, because of the amount of funding available, it was possible for the SWCD's to offer high rates of cost sharing, which in turn accounts, to some degree, for the high percentage of completion for contracted items in the LTA's.

It should also be remembered that this Project was sponsored and governed by local government. I am not certain how these units of government would have reacted to a program imposed on them.

The delegation of certain authorities manifested itself most certainly in the area of performance. The system allowed us to compare the effects of differences in conservation attitudes, economics, and political structures upon attainment of Project goals and objectives. John Streich has already given you a basic idea of the types of agriculture and attitudes of the landowners in the study areas. Now I will try to characterize the conditions in the counties which affected the activities of the five SWCD's:

1. How elected

Carlton	At large
Douglas	Appointed from County Board of Supervisors

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Bayfield	Appointed from County Board of Supervisors
Ashland	" " " " " "
Iron	" " " " " "

2. Place of residence of District Supervisors

Carlton	Urban 0	Rural 0	Farm 5
Douglas	Urban 3	Rural 2	Farm 0
Bayfield	Urban 0	Rural 2	Farm 3
Ashland	Urban 3	Rural 2	Farm 1
Iron	Urban 0	Rural 5	Farm 0

3. Past history of participation with RC&D

Carlton	Excellent
Douglas	Poor
Bayfield	Excellent
Ashland	Good
Iron	Poor

4. District staff

Carlton	3
Douglas	0
Bayfield	0
Ashland	0
Iron	0

5. General attitude toward nonpoint source control programs

Carlton	Excellent
Douglas	Poor
Bayfield	Poor
Ashland	Poor
Iron	

6. Economic condition (per capita income)

Carlton	4,380
Douglas	3,957
Bayfield	3,162
Ashland	3,408
Iron	2,935

7. Attitude toward appropriation of local pollution abatement funds

Carlton	Excellent
Douglas	Fair
Bayfield	Poor
Ashland	Excellent
Iron	Poor

8. Performance

Carlton	Excellent
Douglas	Fair
Bayfield	Good
Ashland	Excellent
Iron	Poor

Although somewhat subjective, I believe that the preceeding gives you a general picture of conditions in the five counties. Of the preceeding, the most important factor in my mind is the political composition of the SWCD. In the case of the Red Clay Project, the best attitudes and performance were found in the one SWCD where the district supervisors were elected at large, rather than being appointed from the county board of supervisors. This is not to say that an appointed district is incompetent or doesn't care. That depends upon the people involved. Obviously, we did a good job with the appointed districts. But, I do think that people who work to be elected to the SWCD are more likely to have the attitudes necessary for successful programs.

Now that I'm this far out on a limb in characterizing the districts, I might as well go one step further and tell you that my opinion is that a voluntary 208 program would work in two of our study areas, but the rest would probably need a regulatory system for a totally effective abatement program. However, I propose that we start with a voluntary program, with enough money to insure that the program has a chance of succeeding, and using a regulatory approach only if the voluntary program fails.

FINDINGS AND SUGGESTED APPROACHES

1. A multiagency voluntary research and demonstration program was successfully implemented in the Red Clay area.

2. Multiagency systems would probably work for some rural 208 nonpoint source control programs where problems are similar.

3. Rural multiagency systems should not be extended across state boundaries due to implementation, funding and standards problems.

4. Multiagency systems should have one set of policies, goals, and objectives for ease of administration and uniformity of goal attainment.

5. Sufficient evaluation and water quality management should be conducted prior to implementation to clearly identify critical areas and parameters thus ensuring cost effective abatement.

6. BMP's should be applied on a site-specific basis.

7. BMP's should be applied only to areas of mans intrusion.

8. High rates of cost sharing cost should be provided to help insure installation of BMP's.

9. SWCD's should be constituted in such a fashion as to represent all of the districts interests. (legislation needed?)

10. SWCD's should have their own trained staff.

11. SWCD's should be involved at the earliest possible date in the development of plans and management strategies.

12. SWCD's should be designated as the local management agency.

13. Where possible, maximum use should be made of institutional and vegetative controls.

14. Local units of government should be encouraged to adopt better operative and maintenance procedures for their road programs.

15. A detailed Conservation Plan of Operation or similar document should be prepared for all identified critical areas.

16. Compliance reviews should be conducted by the District staff.

17. Enforcement responsibilities should rest with the state Water Quality Management Agency.

DEMONSTRATION OF SHORELINE PROTECTION ON LAKE SUPERIOR

by

Tuncer B. Edil[1] and Peter L. Monkmeyer[2]

ABSTRACT

In order to determine the feasibility of controlling the erosion of the Red Clay Bluffs on Lake Superior, shore protection demonstration projects are under way in Ashland County, Wisconsin. Longard tubes - large, flexible, plastic tubes filled with sand - have been selected for use as the demonstration structures at Madigan Beach, on the mainland near the city of Ashland. The design layout includes groins, seawalls, and groin-seawall combinations. At the Indian Cemetery on Madeline Island a rubble mound revetment has been constructed, to protect this historical site.

Baseline data has been obtained to aid in monitoring and evaluating the performance of the shore protection structures. More specifically, hydrographic and nearshore sediment sampling surveys have been conducted at the sites, and soil borings have been performed at nearby control locations to provide geological and geotechnical characteristics of the coastal bluffs and terraces.

A wave hindcast for several storm conditions has been completed. Numerical procedures have been used in conducting the deep water wave hindcast and in propagating the waves into the nearshore zone where they are subject to refraction and shoaling before reaching the breaker zone.

INTRODUCTION

To a large extent the soil in those northern counties of Wisconsin that border on Lake Superior is composed of a distinctive "red clay". This highly erodible material is carried into Lake Superior both by the streams that empty into the lake and by shoreline erosion. In an effort to deal with the resulting recession of the Red Clay Bluffs that extend along a portion of the shoreline, and with the degradation of the nearshore waters, an erosion control program known as the Red Clay Project was initiated.

In 1974 the U.S. Environmental Protection Agency, responding to proposals of the Red Clay Interagency Committee, the local Soil and Water Conservation Districts and the Northwestern Wisconsin Regional Planning and Development Commission, granted federal assistance to four counties

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in Wisconsin - Ashland, Bayfield, Douglas, and Iron, and one county in Minnesota - Carlton, to initiate an erosion and sediment control demonstration project in the "red clay" area of Lake Superior.

The purposes of the original E.P.A.-sponsored study were: (1) the identification and analysis of several demonstration sites for shoreline erosion control in Ashland County, and (2) the establishment of cost estimates for the development of suitable means for effective shoreline protection, particularly in areas which are highly vulnerable to the processes of erosion.

Subsequently, Madigan Beach in Ashland County, Wisconsin (Fig. 1) was selected as the major demonstration site at which Longard tubes were to be installed to determine their usefulness in controlling erosion. The Red Clay Bluffs, which rise up some 60 to 80 feet (approx. 18 to 24 meters) above Lake Superior at this site (Figs. 2 and 3) have been severely eroded and therefore offer an excellent site for a demonstration of the effectiveness of the Longard tubes. The surface of the upland region which extends inland from the crest of the bluffs is a grassy and wooded plain overgrown by a young stand of trees. Extending downward to the lake, in sharp contrast, is the scarred face of the Red Clay Bluffs. Figs. 2 and 3 clearly show that the bluffs are characterized by numerous slides which carry many trees and other vegetation, as well as the red clay itself, down to the beach and eventually into Lake Superior.

The shoreline near the Indian Cemetery on Madeline Island, Ashland County, Wisconsin was selected for the second demonstration. In this case a more conventional structure - a rubble mound revetment - was to be constructed, using locally available materials to prevent the further erosion of this historical site (Fig. 1). For a more detailed description of the background of the project, and also of some of the preliminary field studies of the on-shore characteristics of the sites the reader is referred to Edil, Pezzetta, and Wolf (1975) and Edil (1975).

The present phase of the study is concerned primarily with the offshore and beach characteristics of the sites, as well as the field studies that were undertaken to determine some of these characteristics. The present phase also describes how these characteristics were used to determine the wave climate and how the performance of the structures is to be monitored. A review of the contents of this report follows:

In the following section those characteristics of the demonstration sites which were readily identifiable are described. And in the subsequent sections the results of field studies which were designed to identify the hydrography and the sediment properties of the sites are presented. Finally a brief description of the installation of the Longard tubes and the construction of the rubble mound revetment is offered. Since the structures were only completed in September, 1977 there has not been sufficient time to prepare even a preliminary assessment of their potential. It is expected that such a report will be made available in the future.

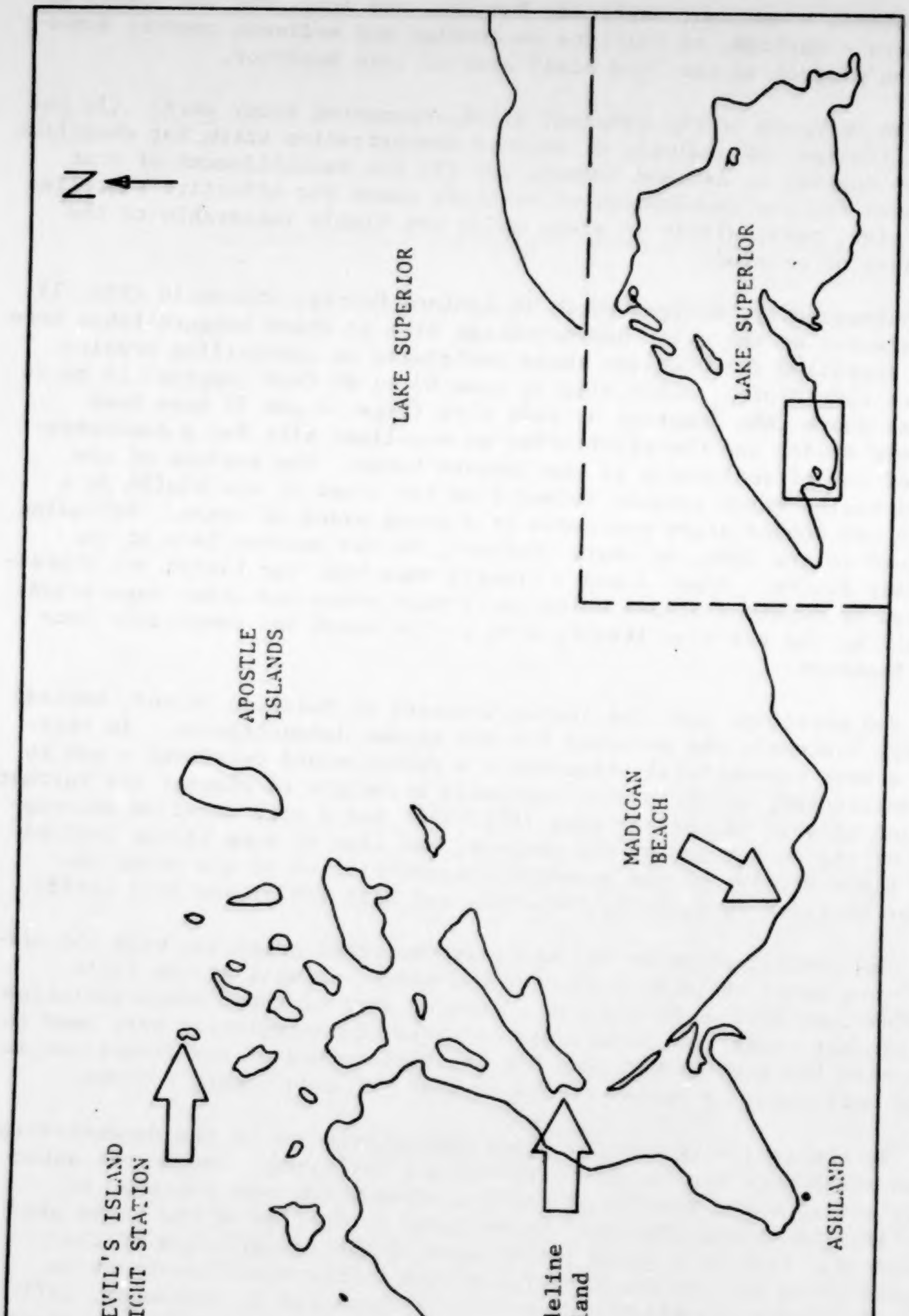

N
LAKE SUPERIOR
LAKE SUPERIOR
APOSTLE ISLANDS
MADIGAN BEACH
DEVIL'S ISLAND LIGHT STATION
Madeline Island
ASHLAND

Fig. 1. Location Map of the Demonstration Site on Lake Superior

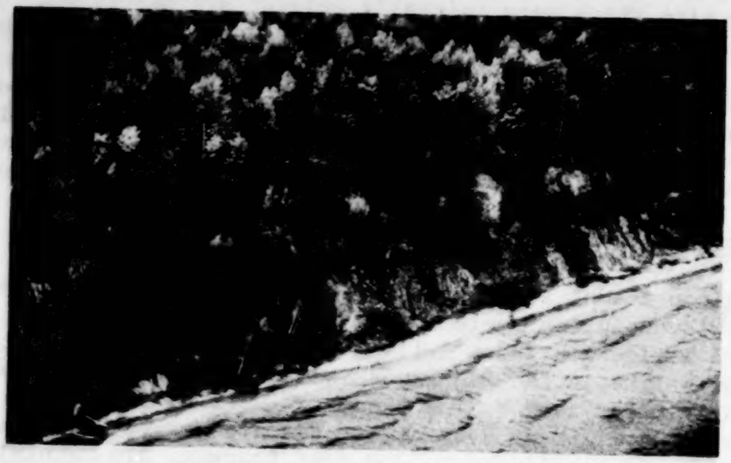


Fig. 2. Aerial View of the Red Clay Bluffs and Madigan Beach

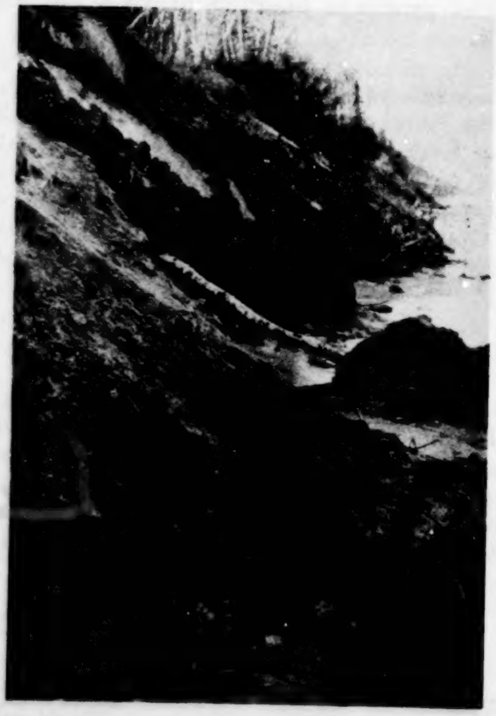


Fig. 3. Profile View of the Red Clay Bluffs and Madigan Beach on Lake Superior, near Ashland, Wisconsin

CHARACTERISTICS OF THE MADIGAN BEACH SITE

In this section, those characteristics of the Madigan Beach demonstration site which were initially evident are described. These include site location, shoreline orientation and fetch exposure, and wind climate. In as much as the hydrographic and soils information initially available were inadequate to properly monitor the erosion and littoral drift, a hydrographic survey supplemented by sediment sampling, and a soil boring program on shore, were undertaken as part of the project. The survey and the boring program are described in subsequent sections.

Site Location

Madigan Beach, a segment of the Lake Superior shoreline in Ashland County, Wisconsin, was selected as the major demonstration site (Fig. 1). The beach is located about 1-1/4 miles (approx. 2 km.) west of the Iron County line in the Bad River Indian Reservation and is accessible from U.S. Highway 2 by Madigan Road, a 2-1/2 mile (approx. 4 km.) secondary road. The study site extends along some 2100 feet (approx. 630 meters) of shoreline from 700 feet (approx. 210 meters) east of the northern end of Madigan Road to 1400 feet (approx. 420 meters) west.

Shoreline Orientation and Fetch Exposure

The Lake Superior shoreline in the vicinity of Madigan Beach extends in an almost unbroken straight line for some 5 or 6 miles (approx. 8 or 9 km.) (Fig. 1). The geodetic bearing of this segment of the coast is approximately N55°W.

The site is exposed to wind and wave action on Lake Superior from the Northwest to the Southeast (moving clockwise). However, it only has a long (greater than a hundred statute miles) fetch exposure from the North-Northeast to the Northeast. The Apostle Islands limit the fetch distances to approximately 20 statute miles from the Northwest to the North, and there is virtually no effective fetch exposure from the Northeast to the Southeast due to the presence of the Keweenaw Peninsula.

Wind Climate

In as much as the demonstration site is in a relatively isolated location, no local wind information was available. However, a search for sources of such information in the vicinity revealed that the Devil's Island Light Station (Fig. 1) had obtained a fairly extensive collection of wind data over the years. This light station is located on one of the northernmost of the Apostle Islands and is manned by the U.S. Coast Guard.

Data for the months of October, November, and December were analyzed for the 9 year period spanning 1968 to 1976. The results of this analysis are presented in Fig. 4 in the form of a wind rose. The frequency of occurrence of five wind speed classes is shown for sixteen compass directions. Also indicated in Fig. 4 are the inclination of the shoreline and the region of effective fetch exposure at Madigan Beach. In

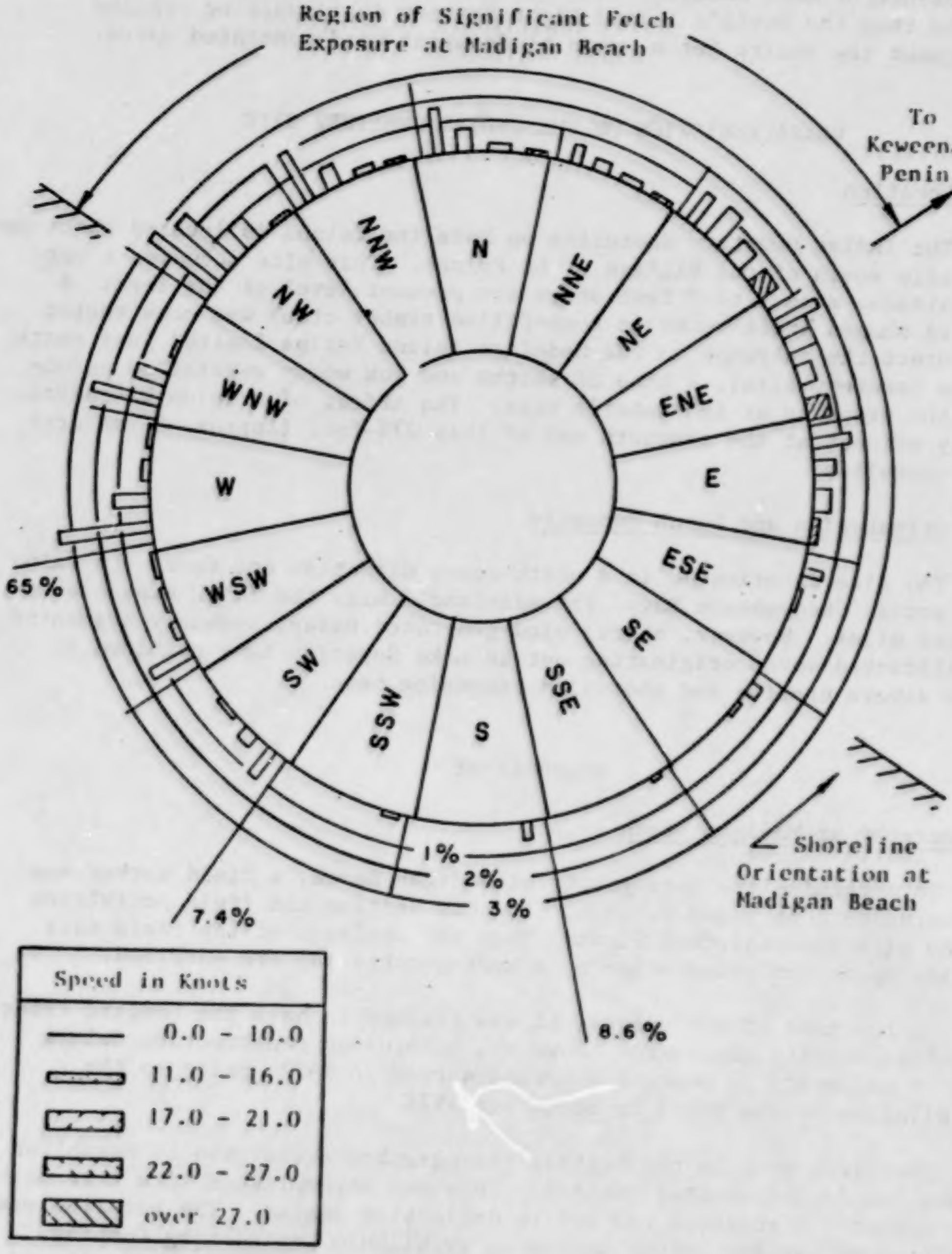


Fig. 4. Wind Rose - Based on Data Obtained at Devil's Island Light Station, Bayfield County, Wisconsin, During October, November and December, from 1968 to 1976

the absence of more detailed wind information in the fetch area, it was assumed that the Devil's Island Light Station data could be applied throughout the entire fetch, when hindcasting wind-generated waves.

CHARACTERISTICS OF THE INDIAN CEMETERY SITE

Site Location

The Indian Cemetery shoreline on Madeline Island is located about one-half mile south of the Village of La Pointe. This site occupies a very low terrace, some 1 to 2 feet above the present level of the lake. A dog-leg shaped break-water (a rock-filled timber crib) was constructed to protect the entrance to the Madeline Island Marina located just north of the cemetery site. A line of shrubs and low woody vegetation parallels the property at the water's edge. The effect of erosion was particularly evident at the southern end of this 275-foot (approx. 84 meters) long shoreline.

Site Orientation and Fetch Exposure

The site is oriented in a north-south direction and faces the mainland across Chequamegon Bay. The mainland limits the fetch exposure to several miles. However, short, wind-generated waves, probably augmented by diffracted waves originating out in Lake Superior have combined to cause severe erosion and shoreline recession here.

HYDROGRAPHY

Hydrography at Madigan Beach

To determine the hydrography at Madigan Beach, a field survey was conducted on June 7 and 8, 1976. In this section the field activities at the site are described first. Then the analyses of the field data leading up to the preparation of a hydrographic map are outlined.

At the time of the survey, it was planned to have the Longard tubes installed shortly afterward. However, unforeseen construction delays made it necessary to conduct a second survey in 1977, prior to the installation of the tubes in September 1977.

The first step in the initial hydrographic survey was to establish a baseline for horizontal control. This was accomplished with a transit-tape survey. A traverse was run by deflection angles. The baseline was tied into an earlier survey conducted by Wilhelm Engineering Company. Several of the same stations were used in both surveys. For details of this and subsequent facets of the hydrographic field survey the reader is referred to Shands (1977).

The hydrographic survey was first conducted in a region extending from 100 feet (approx. 30 meters) offshore to approximately one-half mile (approx. 800 meters) offshore. Depth measurements were made from a Zodiac inflatable boat, which was assembled and launched with relative ease from a nearby beach. The boat was powered by an outboard motor and offered a fairly steady platform for the Raytheon Model DE 719 recording fathometer. Leadline readings were also taken to provide a calibration check for the fathometer.

The location of the boat was determined through triangulation by transit intersection from three stations on shore. Twelve transects were run perpendicular to the shoreline at approximately 200 foot (approx. 60 meters) intervals. To coordinate the depth measurements with the boat's location, four sets of transit readings were taken per transect.

The second phase of the hydrographic survey was conducted in a region extending from the shoreline to 100 feet (approx. 30 meters) offshore. Here, lake bottom elevations were shot with a transit and *Philadelphia* rod. Starting from the easterly side of the site, profiles were run every 100 feet (approx. 30 meters) along the baseline for the first 1100 feet (approx. 330 meters) and then every 200 feet (approx. 60 meters) to station Q. For each profile, elevations were shot at the shoreline and at distances of 25, 50, 75, and 100 feet (approx. 7.5, 15, 22.5, and 30 meters) from the baseline.

Copies of the raw data obtained in this hydrographic survey are given by Shands (1977).

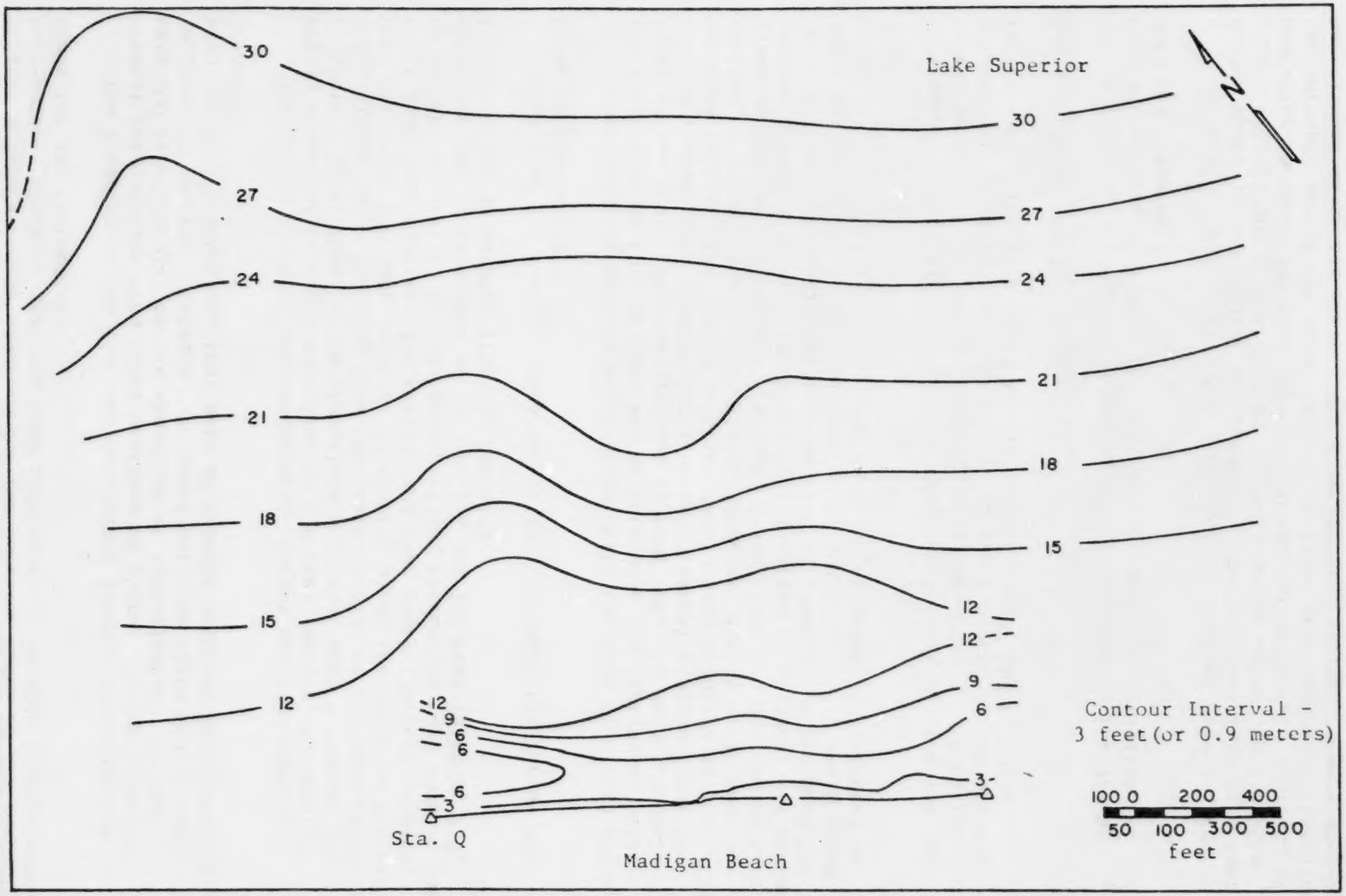
A hydrographic map was constructed using the data from this survey. The first step in this process was to determine the horizontal locations of the boat. The baseline was plotted and, for each triangulation fix, lines were constructed from each transit station along the recorded angles. The boat's location should have occurred at the intersection of these three transit lines. However, due to small inaccuracies in some of the transit readings, these lines did not always intersect at a single point. Therefore, the location of the boat was assumed to be at the intersection of the two transit lines which produced the least deviation in the intersection point location, for a small fixed change of each transit angle. For details the reader is referred to Shands (1977).

Once the boat had been located, the depths were plotted and contoured in 3-foot (approx. 0.9 meter) intervals. The resulting hydrographic map is presented in Fig. 5. The water depths on the map are referenced to the lake level at the site on June 7 and 8, 1976.

Hydrography at the Indian Cemetery

A field survey was conducted on Madeline Island at the Indian Cemetery on June 9, 1976. In this section the field activities at the site are reviewed.

The hydrographic survey was conducted in a manner paralleling the second phase of the Madigan Beach survey. Bottom elevations were shot with a transit and a Philadelphia rod in a region extending from the shoreline to about 100 feet (approx. 30 meters) offshore. Starting at the northern end of the site, several profiles were run from a baseline established along the shore. For each profile, elevations were shot at


Lake Superior
N
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9
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6
6
3
Sta. Q
Madigan Beach
Contour Interval -
3 feet (or 0.9 meters)
100 0 200 400
50 100 300 500
feet

Fig. 5. Hydrographic Map of Madigan Beach, June 7 and 8, 1976

25 foot (7.5 meters) intervals.

SOILS AND SEDIMENT SURVEY

Soils Survey of the Madigan Beach Bluffs

Profile measurements and sediment samples were taken principally at the 60-foot (approx. 18 meter) high bluffs located at the lakeward terminus of Madigan Beach Road. The bluff face at this site has been terraced en echelon by rotational slumping. The average bluff and beach slopes were measured to be 38° and 9° respectively. Both toe and face erosion of the bluffs and the deep rotational slips were evident along the shoreline in the vicinity of this site.

Three bore-holes were drilled on the top of the bluff at the Madigan Beach site and samples were obtained for textural and geotechnical analyses. The borings and observations of the materials exposed on the bluff face indicated the presence of a 15 to 20 foot (approx. 4.5 to 6 meter) thick, reddish-brown, stiff, silty clay layer of low plasticity on the top, underlain by a thick (more than 40 ft or 12 m), very dense brown sandy silt. This highly erodible (cohesionless) sandy silt makes up most of the bluff material and is underlain by a reddish-brown, rather stiff, clay layer of high plasticity, mostly below the lake level. Detailed grain-size analyses of the "red clay" bluff sediments clearly indicate that these deposits are highly variable in their textural characteristics. The bulk composition of the thick glacial deposit sampled consists largely of very fine sand and coarse silt (mean grain size 0.043 to 0.077 mm); no clay-sized components were present in any of the samples taken from this deposit. Hence, the silt and fine sand fractions impart a distinctly "gritty" texture to these sediments and render them cohesionless and highly erodible. The samples taken from the cohesive layers above and below the sandy silt layer also exhibited differences. For example the top layer had 64% silt (0.002 to 0.074 mm grain size) and 26% clay size meterial (<2μ) whereas the bottom layer had only 26% silt but 63% clay size material resulting in distinct differences in their plasticities.

Slope Stability

Slope stability analyses of a number of bluff profiles of Madigan Beach indicated varying safety factors against landslides (Edil and Haas, 1976). Some of the bluffs were extremely steep with low safety factors indicating an imminent state of failure; others had already slipped and reached relatively safe inclinations.

There are a number of factors which seem to contribute jointly to the recession of these bluffs. It is quite difficult to quantify each of these factors. Nevertheless, it appears that the wave action and the resultant erosion and removal of bluff toe material are the most significant factors responsible for the triggering of landslides and bluff recession. However, removel of materials from bluff faces as a result of freezing and thawing (solifluction), precipitation, surface runoff and ground water seepage also contribute significantly to bluff recession.

Borings at the Indian Cemetery

Three borings performed at the Indian Cemetery site in 1976 indicated primarily coarse-grained materials down to a depth of 15 ft (4.6 m) from the ground surface (Stoll, 1976). The boring data indicated the presence of light brown, fine to medium size, medium dense (standard penetration resistance, N according to the ASTM Designation: D 1586-67 of 10 to 15) sand with traces of silt and gravel down to a depth of 7 ft (2.1 m). This layer was underlain by a light brown, fine to coarse size, dense (N ≃ 30) sand with traces of silt down to 11 ft (3.4 m). There was a brown, fine, dense (N ≃ 25) sand layer with traces of silt and gravel below 11 ft (3.4 m). This type of subsurface soil information is particularly useful in assessing the stability of shore protection structures such as the rubble revetment constructed at this site.

Sediment Sampling at Madigan Beach

The beach and nearshore deposits sampled within a zone extending roughly from the water line out to 100 ft (approx. 30 m) consisted mostly of fine to coarse-grained sands, with grain size ranging from 0.16 to 0.97 mm in diameter (Table 1). Since the major bluff deposit contained a very high proportion (84%) of silt, only a small fraction of the bluff materials was retained in the nearshore environment to form the beach deposits; the bulk of the bluff sediments is apparently carried away by the longshore currents.

Table 1. Lake Superior Samples Taken at Madigan Beach, Sedimentological Data June 6-11 1976

Sample	Mean phi	Grain size*	Std dev	Skew-ness	Kurt-osis	% Sand	% Silt	% Clay	%Heavy min.
1	0.93	525.17	2.39	1.57	5.61	89.10	9.40	1.50	11.970
2	1.70	307.98	0.33	-1.09	13.57	100.00	0.00	0.00	11.756
3	1.81	285.73	0.53	-1.11	7.67	100.00	0.00	0.00	5.199
4	0.05	968.12	0.59	-0.04	3.58	100.00	0.00	0.00	8.108
5	-1.70		0.26	10.81	158.45	100.00	0.00	0.00	23.076
	Pebble diameters range from 28 mm. to 59 mm.								
6	-0.20		1.06	0.48	2.51	100.00	0.00	0.00	3.791
7	0.42	749.20	1.42	-0.57	2.07	99.57	0.43	0.00	5.578
8	2.52	174.86	0.71	-0.19	4.57	97.65	2.35	0.00	2.334
9	2.43	185.94	0.62	0.14	3.90	99.18	0.82	0.00	6.560
10	1.96	256.18	0.88	0.35	4.92	96.25	3.75	0.00	3.086
11	2.62	162.71	0.68	-0.98	7.94	97.21	2.79	0.00	3.401
12	1.95	258.99	0.60	-0.44	5.75	100.00	0.00	0.00	6.503
13	0.53	694.02	1.03	-0.14	1.94	100.00	0.00	0.00	3.381

*Grain size is given in microns

Sediment Sampling at the Indian Cemetery

The Indian Cemetery nearshore sediments were primarily coarse-grained, moderately to well sorted sands (Table 2). Medium to coarse sand was observed along the northern half of the beach, while medium-sized pebbles (14 mm in diameter) were noted at the southern extremity of the property.

Table 2. Lake Superior Samples Taken at the Indian Cemetery-Madeline Island, Sedimentological Data June 6-11 1976

Sample	Mean phi	Grain size*	Std dev	Skew-ness	Kurt-osis	% Sand	% Silt	% Clay	%Heavy min.
1	-0.35	1271.25	1.27	0.17	1.52	100.00	0.00	0.00	9.913
	Pebble diameters range from 12 mm. to 29 mm.								
2	0.98	507.76	0.54	0.46	6.16	100.00	0.00	0.00	11.021
3	1.20	434.11	0.52	1.12	4.72	100.00	0.00	0.00	4.632
4	0.89	537.83	0.68	0.46	4.68	100.00	0.00	0.00	57.860
5	0.82	565.97	0.67	-0.69	6.70	100.00	0.00	0.00	12.625
6	0.91	532.31	0.78	-0.84	6.37	100.00	0.00	0.00	13.310
	Pebble diameters range from 26 mm. to 39 mm.								
7	-0.56	1478.63	1.19	0.45	1.85	100.00	0.00	0.00	37.634
	Pebble diameters range from 22 mm. to 30 mm.								
8	0.09	939.74	1.00	-0.53	2.53	100.00	0.00	0.00	15.765
9	0.55	683.31	1.12	-0.90	3.23	100.00	0.00	0.00	15.343
	Pebble diameters range from 15 mm. to 25 mm.								
10	-0.12	1084.27	1.05	-0.43	1.95	100.00	0.00	0.00	9.848
	Pebble diameters range from 22 mm. to 26 mm.								

*Grain size is given in microns

Shoreline Recession

The shoreline was mapped for about 1400 ft (approx. 420 m) northwest, and 1900 ft (approx. 570 m) southeast of the access road to Madigan Beach using 1951 and 1974 photography. Shoreline recession varies from a negligible amount to a maximum of about 50 ft (15 m) in this area. The average amount of recession is about 25 ft (7.5 m) giving a rate of 1.0 ft (0.3 m) per year (Edil, Pezzetta and Wolf, 1975). Photogrammetric mapping of this site was rendered particularly difficult due to the lack of good quality ground survey points, and the obscuring effect of overhanging trees and brush.

Taking the shoreline geometry (bluff profiles) into account and using methods described in the Shore Protection Manual (1973), the volumetric rate of sediment loss was computed to be 5.85 cu.m/m/yr. The average annual loss (total volumetric displacement) was computed as the product of the volumetric rate of loss and the effective length of the shoreline segment. The total volumetric displacement for the 12-mile (approx. 19 km) shoreline along Madigan Beach is approximately 150,000 cu.yd/yr (approx. 115,000 cu.m/yr). In addition to the effective shore length, the height of the bluffs and the nature of the bluff materials are important factors in making this segment of Lake Superior shoreline a critical sediment source.

Approximately 4,000 feet (1219 m) of shoreline was mapped in the vicinity of the Indian Cemetery site on Madeline Island for the years 1939, 1951, and 1973. There has been a considerable change in geometry in the area of the inlet to the Marina, much of which may be attributed to construction. There is, however, a significant amount of natural recession in the area - as much as 65 feet (19.8 m) during the period from 1939 to 1973. The average rate of recession is about 1.6 feet (0.48 m) per year (Edil, Pezzetta and Wolf, 1975). Taking the shoreline geometry (terrace profile) into account, the volumetric rate of sediment loss was computed to be about 0.29 cu. m/m/yr. The average annual loss would be 354 cu. m/yr. for a 1219 m segment of the shoreline west of Madeline Island if the discrete protection works are to be disregarded.

WAVE ANALYSIS

Wave Hindcasting

In order to study the wave climate at Madigan Beach, a numerical hindcasting procedure based on the French spectroangular wave model (Gelci, Cazale, and Vassal, 1957) was developed. In the spectroangular model, the wave energy density spectrum is separated into discrete components, each with a distinct period and direction of propagation. The average energy density in each component is then hindcast separately. Finally, these average energy densities are recombined to produce the wave energy density spectrum at a deep water hindcasting site. Wave heights, representative of the average energy density in each component, may then be calculated from this spectrum.

In this procedure, radial propagation lines which converge at the site of interest are constructed. Grid points are located on each propagation line at intervals of $C_G \cdot \Delta t$, where C_G is the wave group velocity and Δt is the time step used in the numerical procedure. The wave group velocity is assumed to equal $gT/4\Pi$, where g is the gravitational acceleration and T is the wave period of the spectral component being analyzed. This expression for the wave group velocity is only valid for deep water waves and hence is limited to hindcasting of deep water waves. Since the wave energy travels at a speed equal to the group velocity, the length of each propagation line must be at least equal to $C_C \cdot t$, where t is the storm duration, in order to include all the wave energy produced by the storm.

Starting at the outer end of a propagation line, the energy density, defined as the total average wave energy per unit surface area and also referred to as the spectroangular density of the component wave being considered, is computed. This energy density is then "jumped" to the next grid point on that propagation line where the increase (or decrease) in the spectroangular density is determined. The spectral increase (or decrease) term is then added to the energy density which was advected into the grid point and the combined energy density is "jumped" to the next grid point. Thereafter the process is continued until the hindcasting point is reached.

This process is repeated for all spectral components. The computed energy densities are then linearly summed to provide the total energy density, e, at the site of interest. The significant wave height may be calculated using the formula $H_{1/3} = k\sqrt{e}$ where k is a constant depending on the units chosen. Finally, if desired, the component wave heights may be obtained by taking the product of total significant wave height and the ratio of the energy density in each component wave to the total energy density at the site. These component wave heights do not represent actual waves, but the wave energy density distribution in the wave spectrum.

Nearshore Analysis

A wave entering the nearshore zone will be slowed, shortened, and steepened as it moves into progressively shallower water. This process is known as shoaling. Furthermore, a wave arriving at an angle to the shoreline will bend toward alignment with the underwater depth contours, since that portion of the wave in shallower water will be moving with less speed. This process of wave front bending is called refraction.

A numerical program developed by R. S. Dobson (1967) was used to evaluate the effects of refraction and shoaling. This program is based on linear wave theory and utilizes the optical laws of refraction.

Together with the deep water wave heights and directions of propagation, hydrographic information from the field survey of June 7 and 8, 1976 was used for the refraction analysis. A square mesh grid was superimposed on the hydrographic map prepared from the survey data, and the water depths associated with each grid or mesh point were determined. The resultant depth grid was then loaded into the refraction program.

In the nearshore analysis each deep water spectral component was refracted across the grid until the wave either broke, i.e. the wave height reached a value of 0.78d, where d is the depth, or reached a grid boundary. For each spectral component which reached the shoreline at the site, the average breaking wave height and direction of propagation were computed.

Madigan Beach has significant fetch exposure only from the North-Northeast to the East-Northeast due to the presence of the Keewenaw Peninsula and the Apostle Islands (see Fig. 6). Storms which produce the largest waves and hence have the most destructive power come from the Northeast. Storms of comparable magnitude from the North-Northeast, North, North-Northwest, and Northwest will produce wave heights of lesser magnitude, in that order, due to increasing fetch limitations. The computer program was operated over the-above mentioned fetch lengths in order to confirm these conclusions.

SHORE PROTECTION STRUCTURES

Installation of Longard Tubes

Longard tubes - large, impermeable plastic tubes, filled with sand - were initially developed in Europe to provide low cost shore protection. More recently the tubes have also been installed in a few locations in the United States. In general they have been placed as groins or seawalls and seem to provide effective and relatively inexpensive shore protection when located in an appropriate environment. The price range, ease of construction, and versatility make Longard tubes a logical candidate for shore protection demonstrations on Lake Superior.

Direction* (degrees)	Fetch (miles)	(km)
240	36	57
255	240	384
270	105	168
285	96	154
300	19	30
315	17	27
330	15	24

*counterclockwise from the shoreline

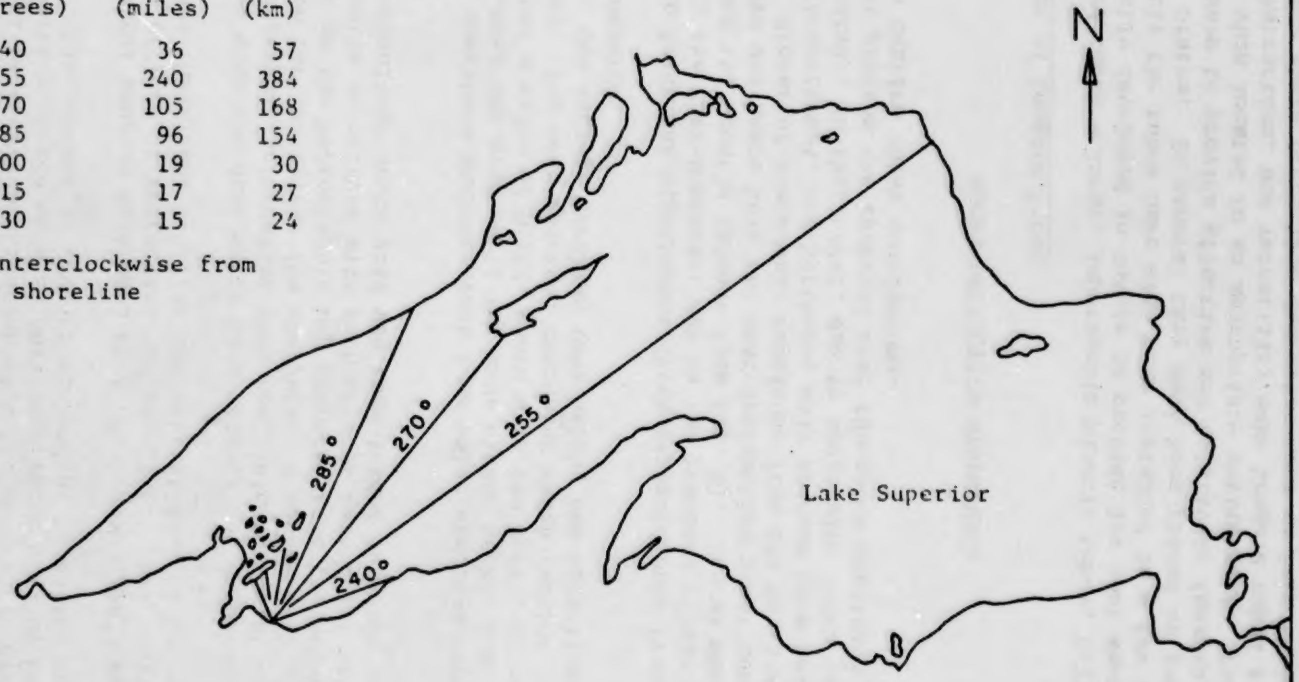
N
Lake Superior
240°
255°
270°
285°

Fig. 6. Fetch Exposure of Madigan Beach

Furthermore, they blend well with the beach environment and can easily be removed if necessary.

While Longard tubes come in various sizes, those used at Madigan Beach are 69 inches (approx. 1.75 m) in diameter and weigh about 3000 lbs/ft (approx. 4500 kg/m) when filled with sand (see Figs. 7 and 8). These are the largest tubes made and the Madigan Beach project includes the largest grouping of these particular tubes in the world. A filter cloth is usually laid beneath the tube and anchored with a secondary tube 10 inches in diameter to minimize scour and tube settlement.

Longard tubes have been placed at five different sites in the Michigan demonstration project (Armstrong, 1976), with a certain amount of success. In developing a field demonstration of these tubes, variations of certain parameters were considered, such as seawall versus groin versus combined seawall and groin; spacing of groins; bluff stabilization; and single tubes versus two tubes on top of each other in the case of seawalls.

The layout of the tubes at Madigan Beach is shown in Fig. 9. Constraints on the length of the public shoreline available for protection made it impossible to develop an ideal layout, in which the groins and seawall sections could be tested independently and free of any interference. One prominent feature of the design was the stabilization of one segment of the bluffs immediately behind and in support of one section of Longard tubes. Bluff stabilization was achieved by regrading the bluff back to a stable inclination of 22° and providing vegetation. Such a procedure has been largely neglected but is expected to be a significant aspect of a successful shore protection project.

The cost per foot of shore protected by the Longard tubes is somewhat variable depending on a number of factors. The total cost of this project was $130,000 for construction and there was an additional $13,500 for engineering services. The total cost of construction included the installation of 1485 feet (approx. 453 m) of Longard tubes plus the modification and stabilization of a segment of the bluffs. In terms of unit cost, this comes to approximately $100 per foot ($300 per meter) of tube installation and $93 per foot ($279 per meter) of shore front. The unit cost goes down to as little as $40 per foot ($120 per meter) of shore front protection in the case of single groins and it is as high as $200 per foot ($600 per meter) of shore front protection in the case of double seawall configuration. The unit cost is $100 per foot ($300 per meter) of shore front protection using a single seawall and $170 per foot ($510 per meter) of shore front using a groin-seawall combination.

Rock Mound Revetment

Due to the immediate nature of the problem, a positive shore protection demonstration was required at the Indian Cemetery site and therefore a rubble mound revetment type of protection was recommended. The site plan and the cross-section of the rubble mound revetment are given in Figs. 10 and 11 (Stoll, 1976). The construction was carried out using locally available materials and was completed in September, 1977 (as shown in Fig. 12). The total cost of construction for this

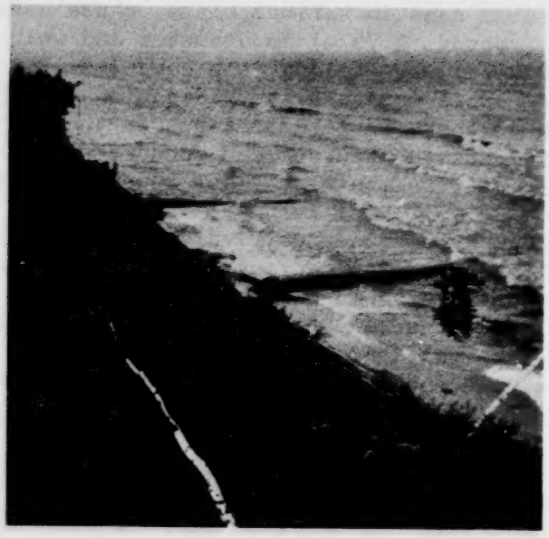

Fig. 7. Longard Tubes Placed as Groins on Madigan Beach

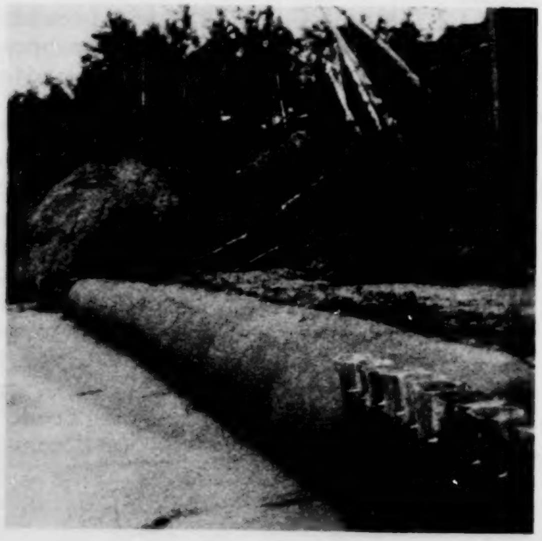

Fig. 8. Longard Tube Placed as a Seawall on Madigan Beach. Note Use of Log Crib to Anchor the End of a Tube

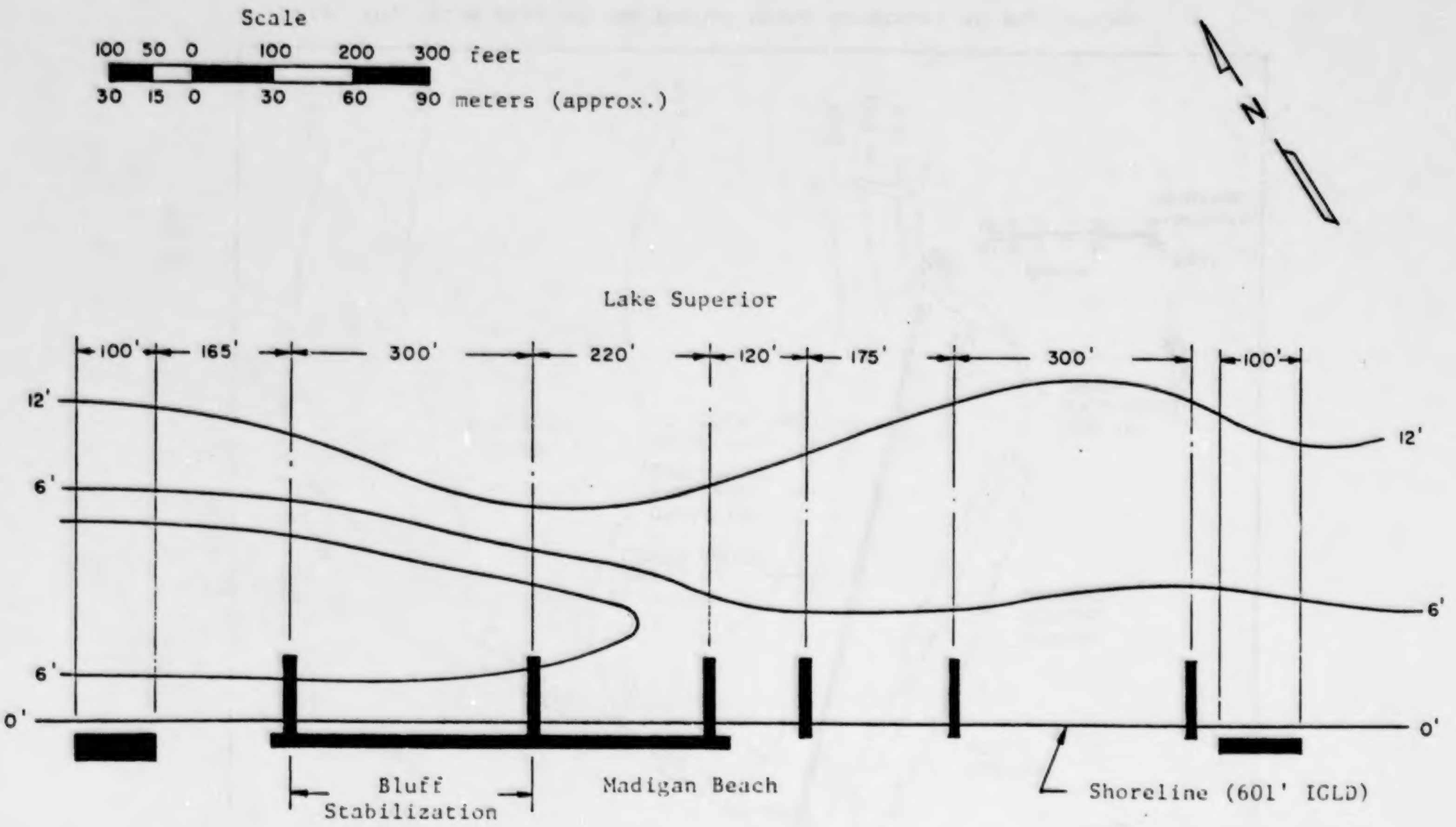
Scale
100 50 0 100 200 300 feet
30 15 0 30 60 90 meters (approx.)
N
Lake Superior
100'
165'
300'
220'
120'
175'
300'
100'
12'
6'
6'
0'
12'
6'
0'
Bluff Stabilization
Madigan Beach
Shoreline (601' IGLD)

Fig. 9. Layout of the Longard Tubes

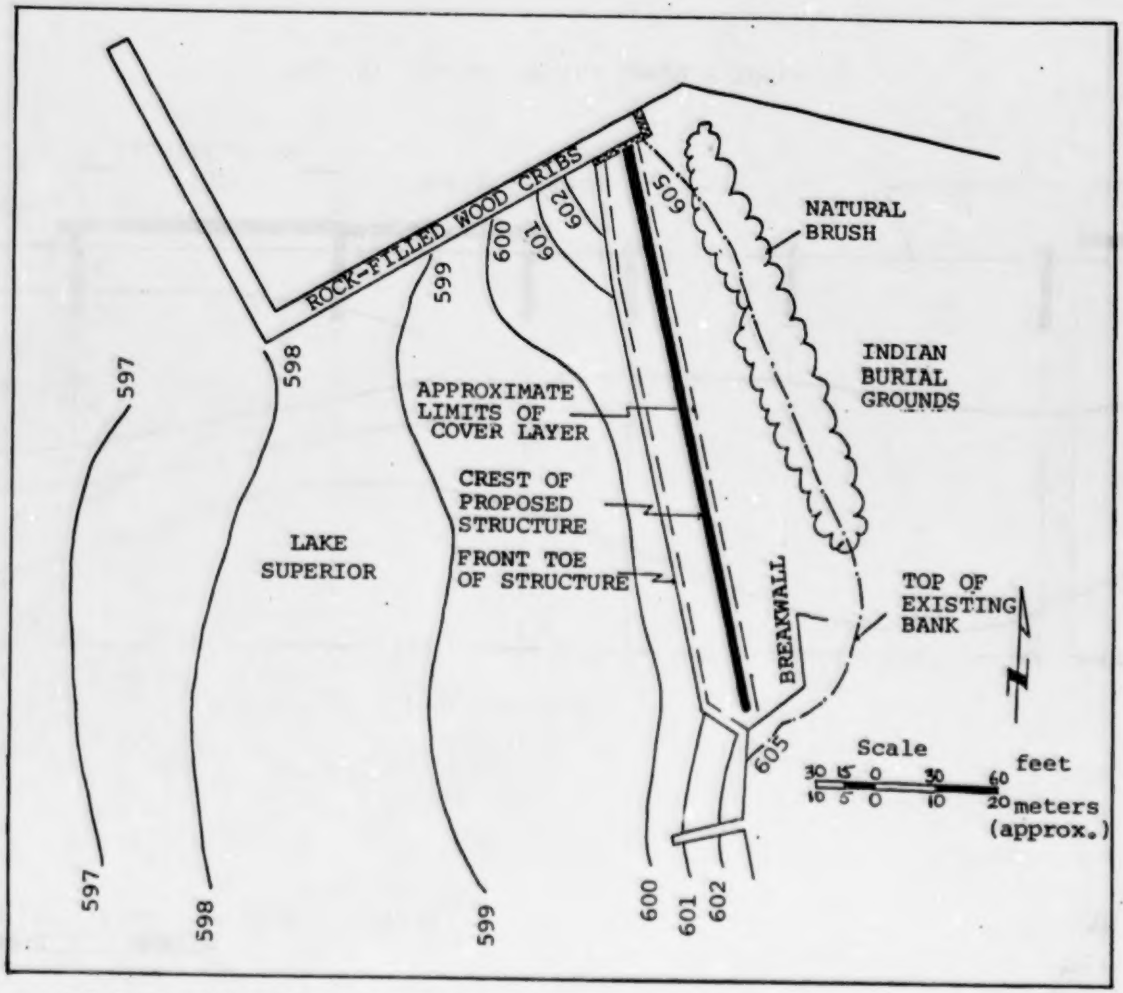
ROCK-FILLED WOOD CRIBS
NATURAL BRUSH
INDIAN BURIAL GROUNDS
APPROXIMATE LIMITS OF COVER LAYER
CREST OF PROPOSED STRUCTURE
FRONT TOE OF STRUCTURE
BREAKWALL
TOP OF EXISTING BANK
LAKE SUPERIOR
597
598
599
600
601
602
605
Scale
30 15 0 30 60 feet
10 5 0 10 20 meters (approx.)

Fig. 10. Site Plan of the Rubble Mound Revetment at the Indian Cemetery Site

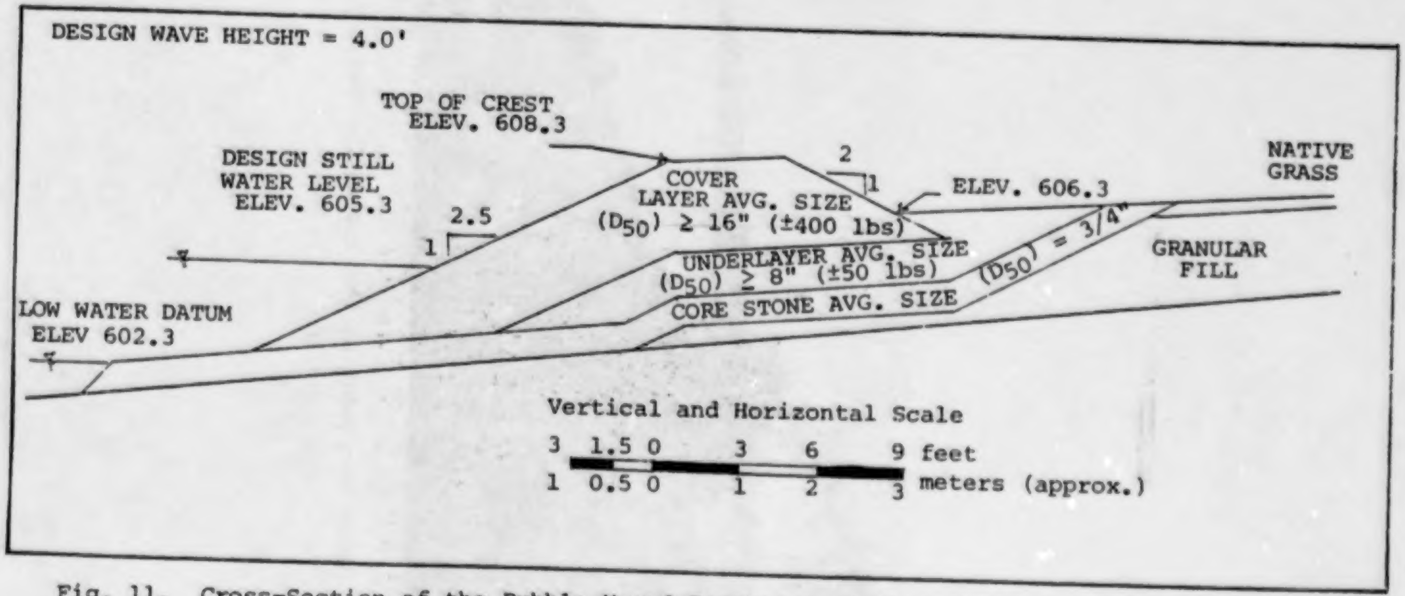
DESIGN WAVE HEIGHT = 4.0'
TOP OF CREST ELEV. 608.3
DESIGN STILL WATER LEVEL ELEV. 605.3
2.5
1
2
1
ELEV. 606.3
NATIVE GRASS
COVER LAYER AVG. SIZE (D50) ≥ 16" (±400 lbs)
UNDERLAYER AVG. SIZE (D50) ≥ 8" (±50 lbs)
CORE STONE AVG. SIZE (D50) = 3/4"
GRANULAR FILL
LOW WATER DATUM ELEV 602.3
Vertical and Horizontal Scale
3 1.5 0 3 6 9 feet
1 0.5 0 1 2 3 meters (approx.)

Fig. 11. Cross-Section of the Rubble Mound Revetment at the Indian Cemetery Site

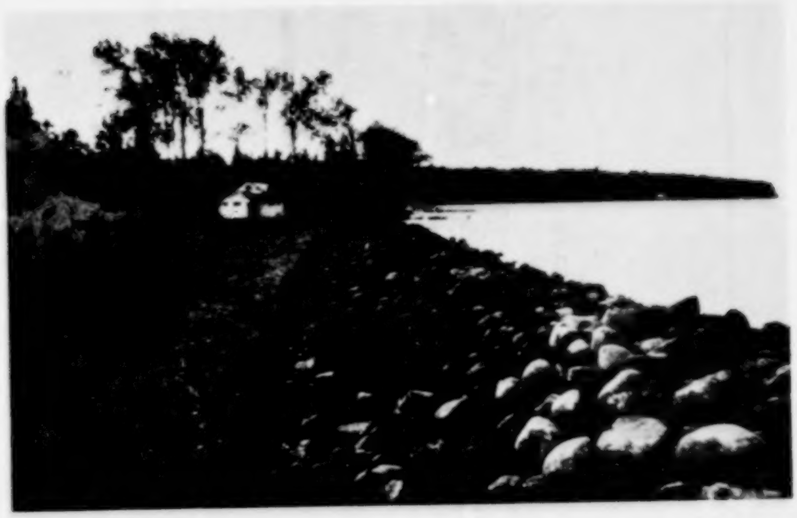

Fig. 12. Rubble Mound Revetment at the Indian Cemetery Site

project was $44,990 and the engineering services cost an additional $11,500. In terms of unit cost, this averages to $205 per foot ($673 per meter) of shore front protected.

SUMMARY

Shoreline demonstration projects are under way at Madigan Beach and Madeline Island, Ashland County, Wisconsin in the red-clay region of Lake Superior. Although the projects are still in progress, the following steps based largely on the field surveys on June 7, 8 and 9, 1976 have been completed:

1. Hydrographic surveys have been completed and hydrographic maps have been prepared.

2. Computer programs that consist of a hindcasting procedure, based on the French spectroangular wave model, and a refraction procedure based on the work of Dobson have been completed to describe the wave climate at the site.

3. Soil borings have been taken at the sites.

4. Sediment samples have been taken in the near-shore region.

5. Soil and sediment data has been analyzed and preliminary estimates of the consequences of bluff-recession have been made.

Brief descriptions of the recently installed Longard tubes and rubble mound revetment complete this preliminary report.

FUTURE PLANS

In order to evaluate the effectiveness of the Longard tubes at Madigan Beach, a continuing program of monitoring will be required over the next several years. At this time plans have been made to repeat the hydrographic surveys made in 1976 and 1977 and to continue the soil surveys at least once during the summer of 1978. Based on the data, estimates will be made of the short-term impact of the Longard tubes on the shoreline. In particular comparisons of the bathymetry, before and after installation, will offer information on the buildup of sand in the area around the tubes. Visual assessments of the ability of the tubes to withstand wave attack will also be made.

Further study of such important phenomena as recession of the bluffs, slumping of the bluffs, wave energy and littoral drift will be continued in 1978.

No plans have been made to monitor the tubes in 1979 since funding does not extend beyond 1978. If new funds are not forthcoming the monitoring program will have to be aborted before a meaningful assessment of the tubes can be made. There is little doubt that the tubes, the bluffs and the area will have to be observed over several years before the demonstration project can be evaluated completely.

ACKNOWLEDGMENTS

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4

ANSWERS Model, A Financial Savings Procedure

by

L. F. Huggins and D. B. Beasley*

Three general, obvious questions come to mind when examining the role of mathematical models in non-point pollution control: 1) are models necessary, 2) why is that so and 3) if the use of a model(s) is warranted, which one(s) should be used? The following material can be subdivided into two broad sections: a philosophical look at the question of modeling needs relative to non-point pollution control planning followed by a brief example application of a particular model developed for use during implementation phases of 208 planning.

In order to provide a basis for the subsequent discussion concerning the first two questions enumerated above a definition of the terminology to be used is in order. One dictionary defines the word model to mean "a miniature representation of a thing; something held up before one for imitation or guidance." This definition can be expanded and restricted to one which describes an environmental quality model as:

> An explicit set of rules (usually mathematical relationships) which attempts to quantitatively describe the behavior of and interaction between groups of environmental variables.

A general dictionary definition of planning is "to form a scheme or method for achieving stated goals." However, some additional requirements must be added when one is concerned with planning for public projects. First, the procedures followed must be rational, i.e. logically consistent with the subject area, and they must be explicitly documented for public scrutiny. Secondly, there should be adequate public participation in formulating desired goals. Third, there should be thorough documentation of evaluation criteria used to rank alternative plans. Finally, there must be documented consideration of and selection between alternative courses of action. Of these four requirements of public planning, the third is the one most often avoided by public officials. This is generally because it involves consideration of factors which are difficult to quantify (e.g., aesthetic factors) and is usually controversial.

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Some Philosophy About Non-Point Source Modeling

It is the authors' belief that the use of environmental quality models is not only the best method to accomplish 208 planning, but that it is the only viable way to proceed in a rational manner with this important and complex task. This conviction is based upon several advantages provided by a modeling approach to planning. First, a mathematical model requires an explicit, logically consistent, and thorough definition of the problem in order to achieve reasonable accuracy. Second, model implementation, usually a computer program, necessitates complete documentation of the analysis procedure employed. Albeit the documentation produced by this process is not always suitable for understanding by the general public, but at least it is subject to scrutiny by professional peers (which is usually better than no evaluation). Third, at present, mathematical models represent the best methodology available for evaluating complex systems. Few persons would disagree with the premise that non-point source pollution control demands an analysis of many complex systems. While currently available environmental quality modeling techniques may still be in a relatively crude state of development, they represent the most powerful analytic planning tool available; furthermore, they can be refined and improved in an evolutionary manner as our understanding of physical processes involved increases. Finally, modeling provides a quantitative and documentable evaluation of the merit of alternative plans of action. Thus, it can be seen that the use of models as a planning tool satisfies three of the four requirements outlined above as being essential to public planning.

While it is necessary that specific benefits provided by models be delineated, it is equally important to point out some planning functions to which models do not make a significant contribution. It is of utmost importance to recognize that models do not set goals, objectives or environmental quality standards that we desire. That vital step is a public responsibility and is accomplished in this country through the political processes of elections and, in some instances, public meetings. Likewise, computer models do not devise a "best" plan for achieving public goals, objectives or standards.

Any planner that claims the "fault" for an unpopular goal or recommended plan of action is that of the computer should be criticized for one of two reasons. Either that planner doesn't understand what the model being used does or, more likely, isn't willing to stand the political heat of defending public policies that do not command overwhelming support. They try to hide behind a "mystical, all-knowing" computer. Actually, inadequate recommendations are the result of either an inadequate model and/or a failure on the part of the planner to request a model's evaluation of suitable alternatives. In either case, the entire blame (as well as the credit for those cases handled well) rests exactly where it should, with the responsible model user. The computer is nothing more than a sophisticated tool to assist in an objective evaluation of proposed alternatives. It can provide a quantitative ranking of the merit of only those alternatives devised by the planner.

While a decision to utilize a model as an integral part of a 208 planning program may be relatively straightforward, the task of selecting which model to utilize of the many currently being developed is neither simple nor non-critical. While Figure 1 attempts to convey the overall difficulty, the acronyms depicted therein by no means constitute a comprehensive list of available models. In fact, the situation is probably best summed up by the philosophical poster which says, "There are as Many Ways as Desires".

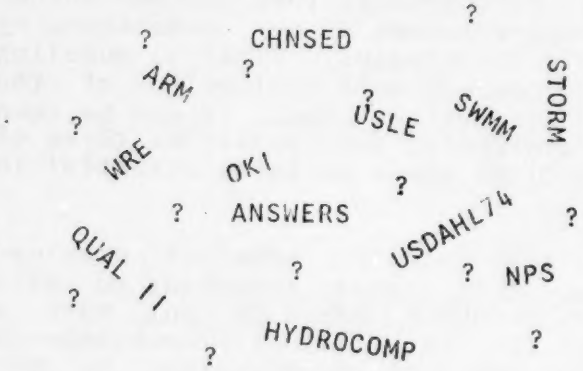


Figure 1. Which model to chose?

How should one sort through this vast number of models to select a "best" one? While almost all model builders have special biases for any model they helped develop, most would concede there is no single "best" 208 model. Specific models are better than others for certain purposes, but no single model currently comes close to quantifying all processes encompassed under the umbrella of non-point source pollution. Furthermore, no single such model is likely to be forthcoming in the near future.

Despite the wide range of models available, it is possible to develop some general considerations which should assist in the task of selecting from among them. However, all considerations to be developed must be viewed in terms of the intended use of the model. Because it is not currently feasible to develop a single model which accurately characterizes all kinds of non-point pollution, models have been developed which concentrate only on certain types of problems. It is necessary that one choose from among a group of models that has been specifically designed for the subclass of problems of primary concern in a given area. In some cases this will necessitate the selection of more than one model in order to analyze the range of pollution problems encountered in a planning region.

At least five general criteria can be identified for model evaluation and selection: 1) the accuracy and detail required of the model output, 2) the effectiveness with which the spatial distribution of pollution sources and parameters are accounted for, 3) the ability of the model to characterize storm (event) related phenomenon, 4) the cost of operating the model and 5) the amount and type of data required. Each of these five criteria merit further elaboration.

The first criteria, required accuracy/detail, is, to a considerable degree, a restatement of the overriding consideration of intended use of the model. However, it is essential to remember that any model is only an approximation of the real thing. Each model is strongly influenced by the preconceived notions of its designer concerning the relative importance of processes the model purports to characterize. Therefore, a model will often quantify some processes of non-point pollution very well while simultaneously doing others poorly. Likewise, the detail of output information varies widely, but is often constrained by the fundamental nature of the model's structure.

Secondly, because we are, by definition, dealing with problems of pollution which originate from diffuse sources it is essential that the model(s) selected be able to assess the influence of the aerial distribution of controlling parameters and of proposed remedial measures. Furthermore, it is important to remember that very few physio-chemical processes important to non-point pollution behave as linear systems. Therefore, the use of arithmetic averages to represent an "effective" value for non-uniform conditions is often only a crude approximation of the influence of the spatial distribution of interacting factors such as soil type, topography, and land use.

Third, the majority of non-point pollution problems, both from agricultural as well as urban areas, are storm induced. Thus, any model designed to evaluate the severity of such problems or the effectiveness of methods for curing them should be capable of simulating a watershed's response to individual real or hypothetical storms (technically referred to as event-oriented models). This is not to infer that a continuous simulation and long-term averages are not germane. Instead, it is a recognition that a comparatively large percentage of the pollution, especially that associated with soil erosion from agricultural areas, results from a small percentage of the annual precipitation associated with infrequent, but intense storms. An accurate assessment of the impact of proposed treatment practices on these storms is essential for determining long-term benefits.

A fourth factor to be considered in choosing a 208 model, and one which requires little additional elaboration, is operational costs. To a considerable degree one must expect that operational cost will increase somewhat as the detail of the output provided by a model increases. It is then the user's responsibility to decide if the additional information justifies its cost.

The fifth and final criterion listed was the data requirements of any model being considered. Everyone should certainly be aware that valid information must be supplied to any model if meaningful results are to be expected. However, while the statement "garbage in-garbage out" is a modeling axiom, it must be pointed out that its converse is not true. The following statement is a more complete description of the attitude that should prevail when selecting a model:

> The accuracy of any model's prediction is limited by both the validity of its input data and the adequacy of the relationships (mathematical) of which it is composed.

In short: the best of input data cannot compensate for an inadequately structured or incomplete model. The governing processes and the relationships incorporated into a model to simulate those processes have a profound influence upon the ultimate accuracy with which it can characterize the purported system.

One additional point needs to be made concerning the assessment of data requirements of a model. It is easy to develop a false sense of complacency about a model which requires little parametric data. However, just because a specific model does not require input data about a variety of catchment characteristics does not automatically make those characteristics unimportant to the real system nor does it relieve the model user of any responsibility. The philosophy which says "Not to Decide is to Decide" is certainly relevant to this situation.

Most individuals tend to shy away from models which require some input values for which they have no published or measured values. Such an attitude may be very unwise. It is valid and generally preferable to assume values for missing data needed by a detailed model than to select a model which does not "require" such data. Models which do not require data concerning parameters which influence simulated processes require acceptance of the model builder's a priori assumption that either 1) those parameters are negligible or 2) they can be accounted for in some simple manner using internal fixed constants to characterize the process. In contrast, if hard data for a detailed model is not available, it is a simple task to utilize the model itself to evaluate the sensitivity of the output to a feasible range of values for missing data.

Based on the above statements, our recommendation is to choose a model on the basis of its inherent relevance to your needs, put as much effort into assembling a data base as the application warrants, then assume a range of reasonable values for any remaining parameters and test how critical those values are to your results. If the output doesn't change significantly, any reasonable values assumed are satisfactory. If the results are very sensitive to the values some additional effort may be warranted to obtain a firmer basis for assigning numerical values. Furthermore, if the latter situation occurs it infers something about alternative models. Either the detailed model is very inaccurate about the manner in which it simulates the influence of this parameter or the simpler model which didn't require such data is grossly in error by neglecting to require it (or both).

Of course, because of the complexity of nature, all models represent only approximations, with widely varying degrees of fidelity, of the real situation. Each model has been tailored by the author(s) to be consistent with preconceived notions concerning the relative importance of each aspect of the overall problem. Thus, any given model may represent one phase of non-point pollution very well while simultaneously handling another very poorly. For this reason, as stated earlier, it is essential that the intended application be kept paramount when choosing a model. In light of the present state-of-the-art of non-point source models it is desirable to view the 208 planning process as at least a two-stage effort. The first stage could be called an assessment phase and the second stage an implementation phase.

The assessment phase of 208 planning is the one currently underway. It is primarily an inventory phase wherein we are trying to identify the problems and assess their relative importance. The primary factor which complicates non-point pollution identification and control is the dispersed nature of its sources. Because of the vast spatial extent of these problems it is essential that we establish priorities concerning how to attack them. For this phase of the 208 planning process, relatively crude models are the most appropriate. They should be aimed at ranking the severity of problems associated with regions, e.g. county sized units, of a state.

As the assessment phase of 208 planning is completed we will move into an implementation stage in which site-specific plans must be formulated, evaluated and selected. This is the point at which public monies must be committed to implement control measures. The modeling demands for this phase are more stringent and require a more detailed data base than a suitable assessment model.

An Example of Implementation Modeling

The material which follows is intended to give a brief introduction to potential payoffs available from a specific, detailed watershed model designed for use during implementation phases of 208 planning for an agricultural area. In its current stage of development, eroded soil is the only pollutant which is directly predicted. Concentrations of other pollutants which are closely associated with soil loss, e.g. phosphorus and cadmium, must be predicted by correlation relations subsequent to obtaining soil loss predictions. The intention of this discussion is to concentrate on the type of results available and their relevance as a planning tool. A detailed discussion of model concepts and the functional relations it incorporates is available elsewhere, Morrison (1977).

In order to provide a background to discuss model predictions it is necessary to give a brief overview of the model structure. The model acronym, ANSWERS, comes from Areal Non-point Source Watershed Environment Response Simulation. The model was developed as a part of the Black Creek Project sponsored by Region V, U. S. Environmental Protection Agency, Section 108.

ANSWERS is a distributed parameter model in contrast to the much more common lumped parameter models. The distinction between these two fundamental model types concerns the computational manner in which they attempt to account for the spatial distribution of controlling watershed parameters. Lumped parameter models use a weighted averaging procedure to obtain effective coefficient values for an entire watershed whereas distributed models utilize an expanded data base which describes the actual distribution of these parameters and then simulates conditions throughout the interior of the catchment. At the risk of oversimplification, the distributed approach attempts to achieve greater simulation accuracy at the expense of increased computational effort.

For computational purposes, a watershed to be simulated by the ANSWERS model must first be subdivided into a grid of small, square elements as shown in Figure 2. The size of an element should be chosen so that all significant variables within its boundaries are approximately uniform (a range of 1 to 4 ha is currently recommended). General mathematical relations are incorporated into the model to describe all relevant physical processes such as infiltration, surface flow, soil detachment, etc. When combined with the data base describing a watershed's physical attributes such as soil type, topography and vegetal cover, these relations simulate the behavior of all significant physical processes occurring within each element's boundaries. Individual elements interact with one another to generate a response for the entire watershed.

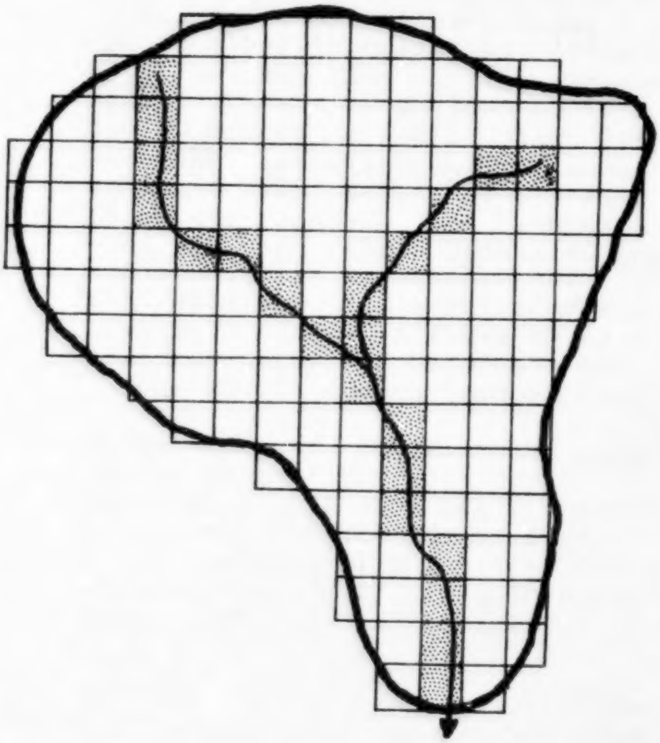


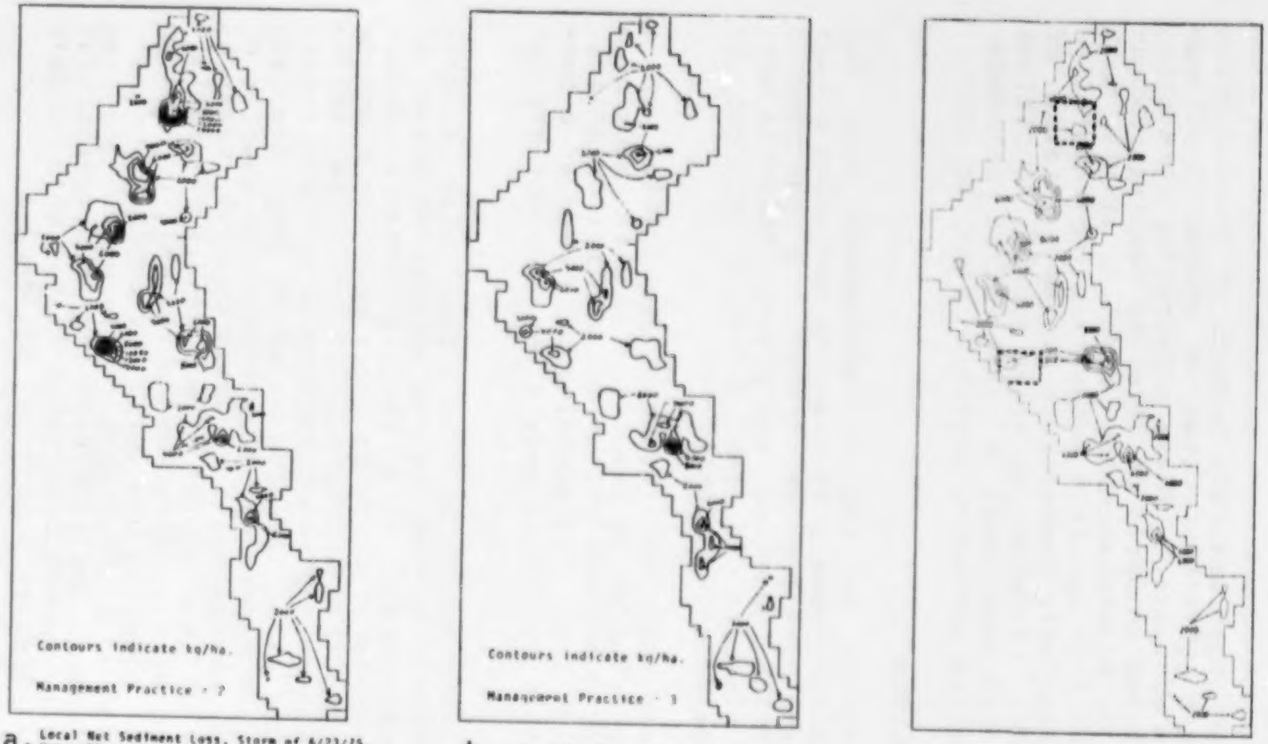
Figure 2. Watershed gridded for ANSWERS simulation.

The actual characterization of an element's behavior begins with antecedent condition data and a rainfall input. Some incoming rainfall is first used to satisfy interception demands of the vegetal canopy. Rainfall in excess of the interception rate becomes available for infiltration and surface retention. Water in excess of surface retention becomes available for overland flow and surface detention. Overland flow from one element serves as an addition source of supply for adjacent elements and flows both over the surface and into any defined channel system. Soil erosion is treated as a process caused by two agents: rainfall and flowing water. Once soil is detached it becomes available for transport by flowing water. Soil which moves into an adjacent element is either transported by water flow in that element or is deposited depending upon prevailing flow velocities (which are based on surface and channel slopes of the element). The equation of continuity is used as the fundamental governing relationship which makes the collection of individual elements act as a composite catchment.

An understanding of the applicability of a model such as ANSWERS to 208 implementation planning can best be illustrated with an example. The example is based on simulating the response of a 714 ha subcatchment of the Black Creek Watershed when subjected to a gaged natural storm in 1975. Figure 3a corresponds to ANSWERS' prediction of sediment detached throughout the catchment during that storm. The "contour" lines were created by connecting points with equal soil detachment. Thus, areas with closely spaced lines correspond to regions of intense erosion activity. Measurements are not available to directly determine the accuracy of these predictions; however, the overall transport predicted by the model at the watershed outlet can be compared with measured results. The detachment patterns shown in Figure 3a resulted from a simulation which predicted the total storm discharge from a 64 mm event to within 9 percent of the gaged amount (19 mm) and predicted the total sediment yield within 13 percent of the observed amount (32000 kg).

Figures 3b and 3c represent simulation results which analyze the relative benefits of two widely differing potential methods of reducing sediment yield and its associated pollution. Figure 3b corresponds to the ANSWERS evaluation of the effect of changing the prevailing tillage practice in this watershed (fall moldboard plowing) to chisel plowing. The predicted sediment yield is less than 1/3 of the gaged amount.

While the erosion control effectiveness of a specific change in tillage management for the entire catchment was indicated in Figure 3b, its cost effectiveness and unforeseen long-term consequences (such as weed and pest problems) often make such measures of questionable wisdom. However, a closer examination of the detailed information on sources of erosion presented in Figure 3a resulted in an evaluation of a different control strategy. That map indicated (by the density of adjacent lines) high detachment rates in two small regions of the catchment. Figure 3c is the result of a simulation which evaluated the effect of changing to chisel plowing on only the 32 ha of the watershed which were experiencing very high erosion (shown as the two small rectangular areas set off by dashed lines in Figure 3c). In-


Contours indicate kg/ha.
Management Practice - 2
Contours indicate kg/ha.
Management Practice - 1

a. Local Net Sediment Loss, Storm of 6/23/75, Upper Black Creek Watershed

b. Local Net Sediment Loss, Storm of 6/23/75, Upper Black Creek Watershed

c.

Figure 3. Simulated soil erosion for alternative land treatment strategies.

tegration of the outflow hydrographs indicated that changing the tillage on only these two small areas would achieve 40 percent of the sediment yield reduction that would result from changing the tillage management of the entire watershed.

Of course, many other possible methods of control which might be even more effective than a change in tillage management could be evaluated. These alternative strategies can often be developed on basis of detailed results from an initial simulation by a comprehensive model. It is this ability to be very site-specific concerning implementation plans and to quantitatively demonstrate overall effects of hypothetical control measures on water quality conditions throughout a watershed that makes a *distributed parameter* model such an effective non-point pollution planning tool.

Summary and Conclusions

The relative merits of and a recommended role for comprehensive watershed models in planning non-point pollution control programs have been delineated. A philosophic overview of non-point modeling was given. Criteria were developed to guide planners in the difficult process of selecting between alternative models.

It was concluded that the intended application of a model was a paramount factor to keep in mind when choosing a model to be used for non-point pollution control planning. It was recommended that 208 planning be viewed as a two-phase process and that different models were appropriate for each phase.

A brief example of how to utilize a particular distributed parameter model during the implementation phases of 208 planning was presented. This example clearly demonstrated the importance of pursuing implementation planning with a highly site-specific approach. The relative pollution control benefits of a given treatment often vary greatly depending upon the exact location on which they are applied. Because of the widespread distribution of sources of non-point pollution, any attempts to apply control measures on an "all-inclusive" basis will likely result in prohibitive costs. While a highly selective approach requires a more comprehensive modeling analysis, the potential financial benefits of such an approach are well worth the required effort. Indeed, it is likely that a site-specific program with carefully ranked priorities is to only viable manner to achieve a successful national 208 program.

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SEDIMENT CONTRIBUTIONS TO THE MAUMEE RIVER.
WHAT LEVEL OF SEDIMENT CONTROL IS FEASIBLE?

by

E. J. Monke and R. Z. Wheaton

The Maumee River delivers about 500 kg/ha (approximately 1/4 ton/acre) of suspended sediments annually into Lake Erie (1,2). This sediment, by also transporting attached chemicals, may be contributing to the eutrophication process in Lake Erie. Most of the sediment is produced as soil erosion on the farms of the largely agricultural Maumee Basin. While sediment rates such as this would seem to indicate that the overall agricultural productivity of the basin is not materially affected, there is some evidence that it has not kept pace with surrounding areas (3).

The Black Creek Watershed was chosen as a representative watershed to help us predict the magnitude and sources of sediment and to demonstrate erosion control for the entire Maumee Basin. It is important then to note differences between the Black Creek Watershed and other parts of the basin.

The soils in the Maumee Basin can in general be classified as glacial till soils, beach ridge associated soils and lake plain associated soils. In the Black Creek Watershed, the area occupied by these soils are 36, 30, and 34 percent, respectively, of the total watershed area as compared to 51, 10 and 39 percent for the Maumee Basin. Since soil erosion is more severe on the rolling glacial till soils than for the other soils, measurements of sediment rates in the Black Creek Watershed may have been lower than the basin average. On the other hand, the Black Creek Watershed drains directly into the Maumee River while most other watersheds in the basin which contain appreciable amounts of glacial till soils are located along the outer edges of the basin. Another difference is that the lake plain associated soils in the watershed do not contain the heavier truly lacustrine or lakebed soils found elsewhere in the basin. However, when compared to the glacial till soils, the lacustrine soils have less surface erosion except at sharp breaks which often occur into incised stream valleys and they are more similar to the lake plain associated soils in the watershed. At some locations, high sediment losses from subsurface drains have been reported for the lacustrine soils, but at other locations, while the sediment concentrations in the flow into drains are high, yields are low because the soils are very impermeable (4,5). In retrospect, we were fortunate to have found a study area which represented the major soil associations of the Maumee Basin as well as the Black Creek Watershed has.

Still, projecting the results of a small area of the total Maumee Basin can be risky. Even if we conclude that the physical conditions of the Black Creek Watershed are representative of the Maumee Basin, we still must account for rainfall variability and distribution. The variability of annual rainfall is such that only after periods of ten or more years are records deemed adequate for predictive purposes. Also a small land area is

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subjected to coverage by intense, convective-type storms which occur in the spring and early summer while the response of the basin is highest from basin-wide, frontal storms which occur in the winter and early spring.

However, even with predictive limitations, the Black Creek Project has been particularly successful in evaluating the amounts of sediment loss likely to occur from agricultural lands in the Maumee Basin, in determining the chemical transport capacity by sediments, in identifying best management practices for water quality control, and in developing a modeling tool for equating the relationship between soil erosion and sedimentation and for selecting cost-effective best management practices. These items will be expanded further in this paper.

SEDIMENT LOSS

Two major drainage areas in the Black Creek Watershed were studied intensively. One drainage area, that for the Dreisbach, is located along the western boundary of the watershed and the other drainage area, that for the Smith-Fry Drain is located along the eastern boundary of the watershed. Some characteristics of these drainage areas and for the Black Creek Watershed are given in Table 1. These two drainage areas, of comparable size, have the greatest differences in soils, topography and land use of the major drainage areas in the watershed. Also note that the characteristics of the drainage area for the Smith-Fry Drain are very similar to the characteristics for the Black Creek Watershed.

Table 1. Characteristics of Drainage Areas

Characteristic	Dreisbach Drain	Smith-Fry Drain	Black Creek Watershed
Drainage area	714 ha	942 ha	4950 ha
Soil groups:			
Lake plain & beach ridge	26%	71%	64%
Glacial till	74%	29%	36%
Land use:			
Row crops	35%	63%	58%
Small grain & pasture	48%	26%	31%
Woods	5%	8%	6%
Urban, roads, etc.	12%	3%	5%
Number of homes	143	28	

Sediment and also nutrient yields from the drainage areas were determined by integrating concentrations with flow rates. The results of these measurements are shown in Table 2 for the years 1975 and 1976. (Data for 1977 are not fully analyzed but data for the first six months of 1977 indicate results between those for 1975 and 1976.) Precipitation for 1975 was about 20 percent above normal and for 1976 it was about 20 percent below normal. Fortunately, these two years represent about as wide a variation in precipitation amounts and patterns as will likely occur over a more lengthy period of record. In 1975, treatment practices were just beginning to be installed and in 1976, the effectiveness of the installed practices was not fully realized because of the low amount of precipitation.

Table 2. Rainfall, Runoff, Sediment Loss, and Nutrient Yields

Parameter	Year	Dreisbach Drain	Smith-Fry Drain	Black Creek Watershed
Rainfall	1975	112 cm	112 cm	112 cm
	1976	70 cm	70 cm	70 cm
Runoff	1975	26.0 cm	29.1 cm	27.5 cm
	1976	10.1 cm	12.4 cm	11.2 cm
Sediment	1975	3470 kg/ha	2130 kg/ha	2370 kg/ha
	1976	380 kg/ha	640 kg/ha	530 kg/ha
Total N	1975	44.1 kg/ha	53.2 kg/ha	48.7 kg/ha
	1976	6.6 kg/ha	10.3 kg/ha	8.6 kg/ha
Total P	1975	5.0 kg/ha	5.4 kg/ha	5.2 kg/ha
	1976	1.0 kg/ha	1.1 kg/ha	1.1 kg/ha

Nutrient yields are given because of the great effect of rainfall, runoff and subsequent sediment loss on nutrient yields. For example, the 40 percent reduction in rainfall from 1975 to 1976 resulted in a 60 percent reduction in runoff, around a 400 percent reduction in sediment loss, and around a 500 percent reduction in total nitrogen and phosphorus yields. Clearly the effects of excess rainfall are magnified in turn by increasing losses of water, sediments and nutrients from a drainage area.

Runoff and sediment yields from the drainage areas of the two drains also present an interesting comparison. Discharge from the Smith-Fry Drain was greater than that for the Dreisbach Drain in both years. Although the drainage area for the Smith-Fry Drain is more level than the drainage area for the Dreisbach Drain, it also has better subsurface drainage and greater interflow through the ditch banks. As shown by hydrographs, base flow in the Smith-Fry Drain always was sustained for longer periods of time than in the Dreisbach Drain.

In 1975, the year with the above normal rainfall, the sediment yield from the Dreisbach Drain was about twice that from the Smith-Fry Drain. However, in 1976, the reverse was true although the yields were greatly reduced. The better land use including the installation of more conservation practices was apparently sufficient to retard runoff and subsequent erosion more in the drainage area of the Dreisbach Drain during a relatively dry year than in the more intensively cultivated drainage area of the Smith-Fry Drain. This reflects the natural sequence of rainfall-runoff events because rainfall must first satisfy the storage capacities of the soil and land surface before runoff begins. A land area with good land use will normally provide more storage capacity than a similar land area with poor land use. However, the storage capabilities of soil and land surfaces are definitely limited, and so with excess rainfall, runoff is soon affected more by land slope. As would be expected then, in years with above normal precipitation, the more sloping drainage area of the Dreisbach Drain will be more erosive and yield more sediment than the more level drainage area of the Smith-Fry Drain.

Our results which are given in detail in the Final Report on the Black Creek Project (6) also show that between 73 and 86 percent of the total sediment yield from both drainage areas was caused by large storm events. A large storm event was arbitrarily defined as any storm which caused more than 2.5 cm (1 inch) runoff from an entire drainage area. In 1975, there were three such events and in 1976, the relatively dry year, two such events.

Our results also show that in normal rainfall years over 97 percent of the sediment loss is likely to originate from land surfaces. Since only about five percent of this at most is estimated to have occurred from ditch bank sluffing and channel scouring, erosion mostly from cultivated fields causes the large bulk of sediment loss from the Black Creek Watershed.

Tile systems only contribute between one and two percent of the total sediment yield from the Black Creek Watershed. This was also true for a 43-acre tile drainage system on Hoytville silty clay located a few miles south of the Black Creek Watershed (7). On the other hand, Schwab et al. (4) measured average annual sediment losses of 2360 kg/ha from tile drained plots where the only drainage provided was through tile drains as compared to 3690 kg/ha for surface drainage only. The plots were in a predominately Toledo silty clay lakebed soil. However, in another lakebed soil, Paulding clay while sediment concentrations in seepage into tile drains were high, yields were nevertheless low because soil permeabilities were also low (5). Research is obviously still needed to determine the extent of the problem and also to determine the causative factors for high sediment losses from some tile drains in the Maumee Basin.

NUTRIENT YIELD

The constituent forms of nitrogen and phosphorus available in runoff from the Dreisbach and Smith-Fry drains are given in Tables 3 and 4. Normally over 90 percent of the total phosphorus transported from the Black Creek Watershed is attached and moved by sediment particles. However, in 1976, a fairly high percentage of the phosphorus was transported as soluble inorganic phosphorus. This was especially true for the Dreisbach Drain because of the large number of outfalls which delivered septic tank effluent into the drain. Septic tank effluent is also relatively constant from year to year and so its influence is greatest in dry years. With nitrogen, only about 40 to 60 percent of the total nitrogen is attached and moved by sediment particles.

Table 3. Percent of Nitrogen Forms Transported

Drain	Year	NH_4^+ -N	NO_3^- -N	Sol Org N	Sed N
Dreisbach	1975	4.1	27.2	5.2	63.5
	1976	12.9	36.5	8.1	42.5
Smith-Fry	1975	2.8	35.7	3.2	58.3
	1976	5.8	53.4	3.0	37.8

Table 4. Percent of Phosphorus Forms Transported

Drain	Year	Sol Inorg P	Sol Org P	Sed P
Dreisbach	1975	6.9	2.4	90.7
	1976	19.0	4.2	76.8
Smith-Fry	1975	2.6	1.8	95.6
	1976	5.9	3.2	90.9

In the Maumee Basin, chemical transport by sediments is likely because of the large amount of colloidal-clay particles in the runoff which offer large relative surfaces for attachment of chemicals. We have concluded that we can reasonably predict the phosphorus yield from an agricultural watershed from the sediment yield. With nitrogen, there are more complexities. We have noted a poorer correlation between total phosphorus and amounts of sediments in the Maumee River as compared to Black Creek. Part of the reason may be the higher input into the Maumee River of soluble inorganic phosphorus by industries and municipalities. The constitutive forms of phosphorus could well give us additional information regarding the source of phosphorus in rivers or other bodies of water.

During the erosion-sedimentation process, separation and segregation of primary soil particles takes place continually from the interrill areas which are mostly impacted by raindrops to streams where the major force involved is due to flow. Materials which are most easily transported are the colloidal clays or organic fractions with relatively low densities. These soils materials characteristically have large amounts of attached nutrients per unit weight of the soil. This increased amount of nutrients over the same weight of original soil before the soil is eroded is known as enrichment. The enrichment factor is likely also to be higher with erosion from a well fertilized soil with good tilth but the total amount of nutrients lost will usually be less than from a poorer soil because of its resistance to the erosion process (8). Average yearly concentrations of total nitrogen and phosphorus which were attached to suspended sediments are shown in Table 5. Also shown are the average concentrations of these nutrients on in situ soils in the Black Creek Watershed and an enrichment ratio giving the relationship between the nutrient concentrations on the sediments and in the relatively undisturbed soil mass.

Table 5. Average Yearly Concentrations of Total Nitrogen and Phosphorus Attached to Soils and Sediments, 1975-76.

Soil or Sediment	Total N (μg/g)	Enrichment ratio	Total P (μg/g)	Enrichment ratio
Watershed soils	1760		680	
Sediment:				
Stream	8900	5.1	1800	2.6
Tile drains	3600	2.0	950	1.4
Septic tank	24000		19000	
Surface runoff	8800	5.0	1600	2.4

BEST MANAGEMENT PRACTICES

In the Black Creek Watershed, the obvious sources of sediment--ditch bank sluffing, channel scouring, and gullies at the upper ends of most of the drains--were treated first. These problem areas were highly visible and acted more like "point" sources within the generally classified nonpoint source watershed. Treatment consisted of shaping, seeding and sometimes armoring the ditch banks, installing grade stabilization structures in the channels, and establishing grassed waterways at the upper ends of the drains.

While the professional opinion was that these practices would not by themselves do much to correct the erosion-sedimentation problem in the watershed, this was not the opinion of the landowners. We have concluded that a certain amount of this type of work will be required in most 208 watersheds. And properly so because aesthetic considerations are part of the solution to any pollution problem.

Field and ditch border strips were a practice which was accepted fairly well by the farmers in the Black Creek Watershed. The primary benefit of the border strips is to protect critical areas often near ditches and roads from eroding. However, their function as filter media has been grossly exaggerated. For the most part they are not parts of channels and, if they are, flow is often so concentrated across them that they become ineffective as filters. To be effective, overland flow should be more-or-less evenly distributed across them such as with the grass or small grain strips in a contour strip-cropping scheme.

A type of parallel, tile-outlet terrace was accepted much more readily by farmers in the watershed than previously expected. However, terraces allow a farmer to intensively farm his sloping fields which is something he would like to do anyway. Although the effectiveness of PTO terrace systems in the watershed have not been evaluated, trap efficiencies as high as 95 percent have been reported elsewhere (9).

Although the border strips, PTO terrace systems, and grassed waterways do cover part of the land area which is contributing to more than 92 percent of the sediment from the watershed, they protect only a small fraction of this land area. Most of this land area, if cultivated, could be protected by altering tillage methods. However, minimum tillage has been accepted slowly because of the cool climate and the rather tight, poorly drained soils with which most of the farmers have to contend. Fall turn-plowing is also practiced for mostly the same reasons, although chisel-plowing which leaves some residue on the surface is gaining some acceptance.

SEDIMENT REDUCTION

The objective of the Black Creek Project was to demonstrate methods for reducing the amount of sediment and associated chemicals from agricultural lands into the Maumee River and eventually into Lake Erie. An oft-stated goal was a reduction of 50 percent. We believe this to be possible but not without more minimum tillage and residue management on some of the more sloping cultivated fields in the Maumee Basin.

Two years of record for the Black Creek Watershed, during which practices were being installed, are obviously insufficient to reliably predict the effect of these practices on sediment reduction. However, we estimated that about a 20 percent reduction has been accomplished by channel improvements, grassed waterways, border strips, PTO terraces, and the modest amount of minimum tillage introduced into the watershed.

We arrived at the 50 percent reduction figure by taking advantage of a watershed simmulation model by the acronym, ANSWERS (10). This model takes into account the areal differences in soils and topography and is based on soil erosion data gathered previously on the watershed and elsewhere. With ANSWERS we can play "what if" games and from this form strategies for reducing erosion in a cost-effective manner.

Results from this model described in more detail in this publication (11) show for a late spring storm that sediment losses from the 714 ha (1780 acres) drainage area of the Dreisbach Drain could have been reduced by one-third by just chisel plowing 32 ha (80 acres) which were actually fall turn-plowed.

This is only the result for one storm but it clearly demonstrates that sediment loss can be significantly reduced by controlling erosion on critical land areas. Some form of minimum tillage operation will be required in the Maumee Basin along with the practices which found acceptance in the Black Creek Watershed to reduce sediment loss to the 50 percent level, but minimum tillage need not be spread over large areas if the critical areas are treated. ANSWERS provides a planning tool for identifying these areas.

DISCUSSION

The Black Creek Project was initiated to demonstrate the effect of land use on water quality. Improved water quality is a desirable goal but equally important to the nation is the conservation of our soil resource.

Unfortunately, there is every indication that erosion of cropland has become more serious in the past several years. In the 1975 National Water Assessment, Soil Conservation Service officials have estimated that water erosion is washing away soils on the nation's cropland at an average annual rate of 20 t/ha (9 tons/ac) nearly twice the rate considered acceptable by soil conservationists (12). Luther Carter also stated in Science that despite the $15 billion spent on soil conservation since the mid-1930's, soil erosion remains one of the biggest, most pervasive environmental problems facing the nation (13). In a CAST report which was submitted to Congress conclusions reached were that one-third of all cropland in the United States was suffering soil losses too great to be sustained without a gradual, but ultimately disastrous decline in productivity and that we are also less effective today in controlling erosion than 15 years ago (14).

Most best management practices for reducing sediment loads into our water resources are also effective practices for controlling erosion on our soil resources as well. This is a fortunate circumstance and should be utilized to its fullest potential.

SUMMARY

Sediment and sediment-borne chemicals have been measured in a continuous fashion from the Black Creek Watershed. Sediments loads are highly variable reflecting the variability of storm events causing sediment-producing erosion. About 90 percent of the phosphorus which was discharged from the watershed was transported by sediments. Between 40 and 60 percent of the nitrogen was transported by sediments. A significant reduction of sediment into the Maumee River depends on the application of minimum tillage practices to critical land areas. A simulation model called ANSWERS could become a valuable planning tool for finding cost-effective measures for reducing sediment production in the Maumee Basin.

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ALGAL AVAILABILITY OF SOLUBLE AND SEDIMENT PHOSPHORUS IN DRAINAGE WATER OF THE BLACK CREEK WATERSHED

by

R. A. Dorich and D. W. Nelson*

Phosphorus (P) has been shown to be the nutrient most limiting algal growth in surface waters of the Great Lakes Region of the United States. Furthermore, addition of P to many bodies of water in this region induces accelerated growth of aquatic organisms and ultimately results in an algal bloom and nuisance weed accumulation. Following the death of these photosynthetic organisms, degradation of the cells by aerobic bacteria leads to rapid depletion of dissolved oxygen in a portion or all of the water column in the lake and numerous water quality problems result. Development of anaerobic conditions in a lake system is a key characteristic of an advanced state of eutrophication.

The death of photosynthetic organisms and subsequent aerobic breakdown of dead biomass was the major cause of oxygen depletion in over 6600 square kilometers of the hypolimnion of the central basin of Lake Erie in 1970. The excessive algal growth in Lake Erie was assumed to result from high P loadings to the lake from municipalities, industries, and nonpoint sources. Therefore, P input into Lake Erie has received considerable attention in recent years. Although point source discharges were identified as major contributors of pollutants to Lake Erie, agricultural activities in the Maumee River Basin were suggested as a major contributor of sediment and related pollutants to Lake Erie. In response, a cooperative project involving the Allen County (Indiana) Soil and Water Conservation District, the Soil Conservation Service and Purdue University was initiated (funded by a U.S. Environmental Protection Agency Demonstration Grant) to assess the role of agriculture in pollution of the Maumee River and to evaluate management alternatives in crop production to minimize impacts on water quality.

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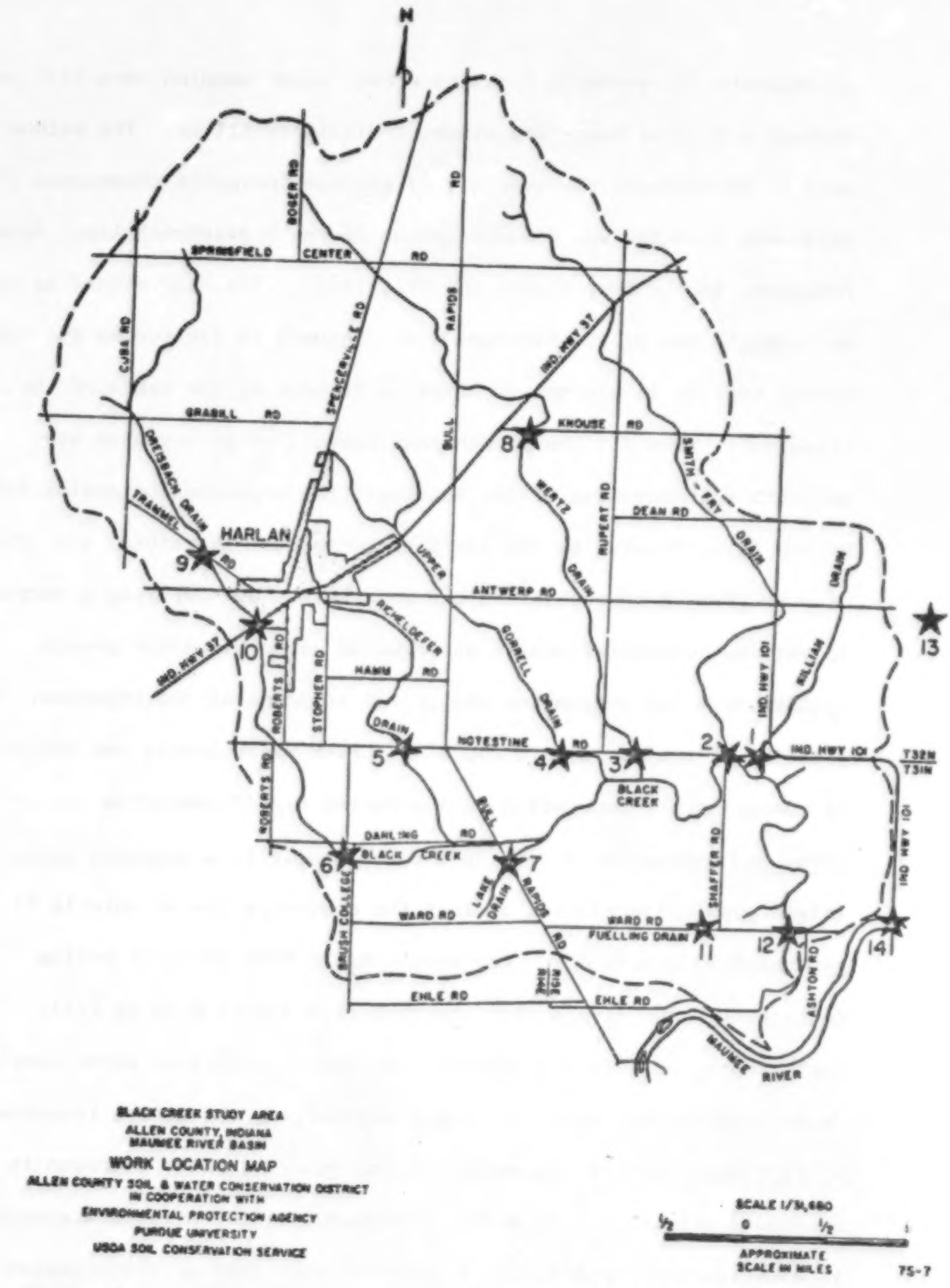
The Black Creek Drainage Basin, Allen County, Indiana was used as a test watershed for the project because it is typical of small subwatersheds along the Maumee River. Chemical measurements of P loading can be used to indicate the quantities of P transported from soil to water systems. However, the majority of P deposited in waters is sediment bound. In order to effectively quantitate the impact of P input on the water quality of the Maumee River (and ultimately to Lake Erie), the proportion of total P transported which is available to algae must be determined. Therefore, the objectives of this study were: (i) to determine the quantities and proportions of soluble and sediment-bound P which were available to algae and (ii) to determine the availability of sediment-bound P fractions to algae.

MATERIALS AND METHODS

PAAP Bottle Test for the Algal Availability of Soluble Phosphorus

Four-liter water samples were obtained following rainfall events on March 28 and June 30, 1977 from seven sites (Figure 1) within the Black Creek Watershed, Allen County, Indiana. Following centrifugation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BOGER RD
SPRINGFIELD CENTER RD
CUBA RD
SPENCERVILLE RD
BULL RAPIDS RD
IND. HWY 37
GRABILL RD
KNOUSE RD
DREISBACH DRAIN
TRAMMEL RD
HARLAN
WERTZ DRAIN
RUPERT RD
SMITH - FRY DRAIN
DEAN RD
UPPER
ANTWERP RD
RICHELDEFER DRAIN
GORRELL DRAIN
ROBERTS RD
STOPHER RD
HAMM RD
IND. HWY 101
KILLIAN DRAIN
NOTESTINE RD
BLACK CREEK
T32N
T31N
SHAFFER RD
DARLING RD
BLACK CREEK
BRUSH COLLEGE
LAKE DRAIN
WARD RD
FUELLING DRAIN
ASHTON RD
EHLE RD
R14E
R13E
MAUMEE RIVER
1
2
3
4
5
6
7
8
9
10
11
12
13
14
BLACK CREEK STUDY AREA
ALLEN COUNTY, INDIANA
MAUMEE RIVER BASIN
WORK LOCATION MAP
ALLEN COUNTY SOIL & WATER CONSERVATION DISTRICT
IN COOPERATION WITH
ENVIRONMENTAL PROTECTION AGENCY
PURDUE UNIVERSITY
USDA SOIL CONSERVATION SERVICE
SCALE 1/31,680
1/2
0
1/2
1
APPROXIMATE SCALE IN MILES
75-7

Figure 1. Water sampling sites within the Black Creek Watershed, Allen County, Indiana.

to separate the sediment from the water, water samples were filtered through a 0.45 μm mean-pore diameter Millipore filter. The method used in determining the quantity of soluble inorganic phosphorus (SIP) available to algae was a modification of the Provisional Algal Assay Procedure Bottle Test (PAAP) (US EPA, 1971). The PAAP method is based on Liebig's Law of the Minimum, i.e., "growth is limited by the substance that is in minimal quantity in respect to the needs of the organism". When all the growth requirements of an organism are met with the exception of one nutrient, the organisms potential for growth is controlled by the limiting nutrient. Therefore, the effect of a nutrient's concentration can be assessed by supplying a nutrient in varying concentrations to an organism given all other growth requirements and evaluating the growth response of the organism. The quantity of available P in the Black Creek Water sample was calculated by comparing the population of a selected alga(*Selanastrum capricornutum*), grown for 4 days in a water sample to a standard curve (algal population plotted against the concentration of soluble P) generated by growth of *S. capricornutum* in PAAP nutrient medium containing known levels of P (ranging from 0.0 to 0.20 μg P/1). Furthermore, by adding a specific nutrient directly to water samples (a nutrient spike) under study and quantifying the growth response of *S. capricornutum* , a comparison to the assay organism's growth in unamended samples can be made. A response in the organism's growth in water samples spiked with a nutrient over that of the organism grown in the unamended water sample indicates that the specific nutrient was deficient in the sample in respect to the needs of the organism. To determine the nutrient limiting algal growth in water samples, phosphorus (0.1 mg P/1) and micronutrients (complete range used in PAAP medium) were added to separate aliquots of all samples and the effect of the added nutrients on the growth of S. capricornutum determined.

Algal Availability of Sediment-bound Phosphorus

Sediment collected by centrifugation of each water sample was resuspended in deionized water, diluted to 50 ml to create a sediment suspension concentrate, and sterilized by exposure to 4 megarads of gamma radiation. Aliquots of the sterilized sediment suspension concentrates were used to prepare the sediment-algal cell mixtures for incubation. An attempt was made to add a constant quantity (37.2 μg of total P per flask) of sediment-bound P to 250 ml flasks containing 60 ml of PAAP minus P medium. After a two week incubation at $26 \pm 1^{\circ}C$ and 4300 lux (fluorescent light), the entire contents of each flask were analyzed for P components.

The method used to determine the quantity and fractions (NH_4F, NaOH or HCl-extractable) of sediment-bound P available to algae was a modification of a method developed by Sagher and Harris (1975). The Sagher and Harris method consists basically of a two-part test system: (i) a sediment-algal incubation (in PAAP minus P medium) to assess the quantity of available sediment P by following changes over a 4 week period in the amounts sediment P sequentially extracted with NH_4F (0.5 N, pH 7), NaOH (1 N) and (ii) a sediment-free algal incubation in PAAP medium (containing 0.2 mg P/1 which corresponds to partial availability of sediment P in sediment-algal incubations) to assess the extractability of algal P by the same sequential NH_4F, NaOH and HCl procedure. Because part of the phosphorus extracted from the sediment-algal mixture originated from algal cells, the results of extractions of the sediment-free incubation were used to correct values obtained from the extraction of the sediment-algal incubations.

RESULTS AND DISCUSSION

Algal Availability of Soluble Phosphorus

(*Selanastrum capricornutum* exhibited a typical sigmoid growth rate at medium and high levels of P (0.05, 0.075, 0.1 and 0.2 mg P/l) in the growth medium. Figure 2 illustrates the growth rate of *S. capricornutum* in medium containing 0.1 mg P/l. At the 0.015 mg/l concentration of P, the algal growth rate curve overall was flatter and the portion normally labelled as "logrithmic" was much less steep than those of higher P levels. The stationary phase of growth was initiated after 96 hrs of incubation for all treatments, but occurred at lower cell densities for each decrease in P concentration.

Figure 3 shows the relationship between cell density after 96 hours and initial P concentration of the PAAP medium. The cell density remained relatively constant at P concentrations greater than 0.1 mg/l. A similar growth response has been observed by other investigators who have shown maximum algal growth at a P concentration of 0.075 mg/l (Fitzgerald and Uttormark, 1974). This level (0.1 mg/l) represents the P concentration at which cells were apparently fulfilled in their need for P for the rate at which they were growing in these incubations. This leveling of algal growth at P concentration above 0.1 mg/l may be looked upon in this experimental system as the critical level of P or that level of available P at which nearly maximum cell production takes place. Furthermore, data observed throughout this study indicates that *S. capricornutum*

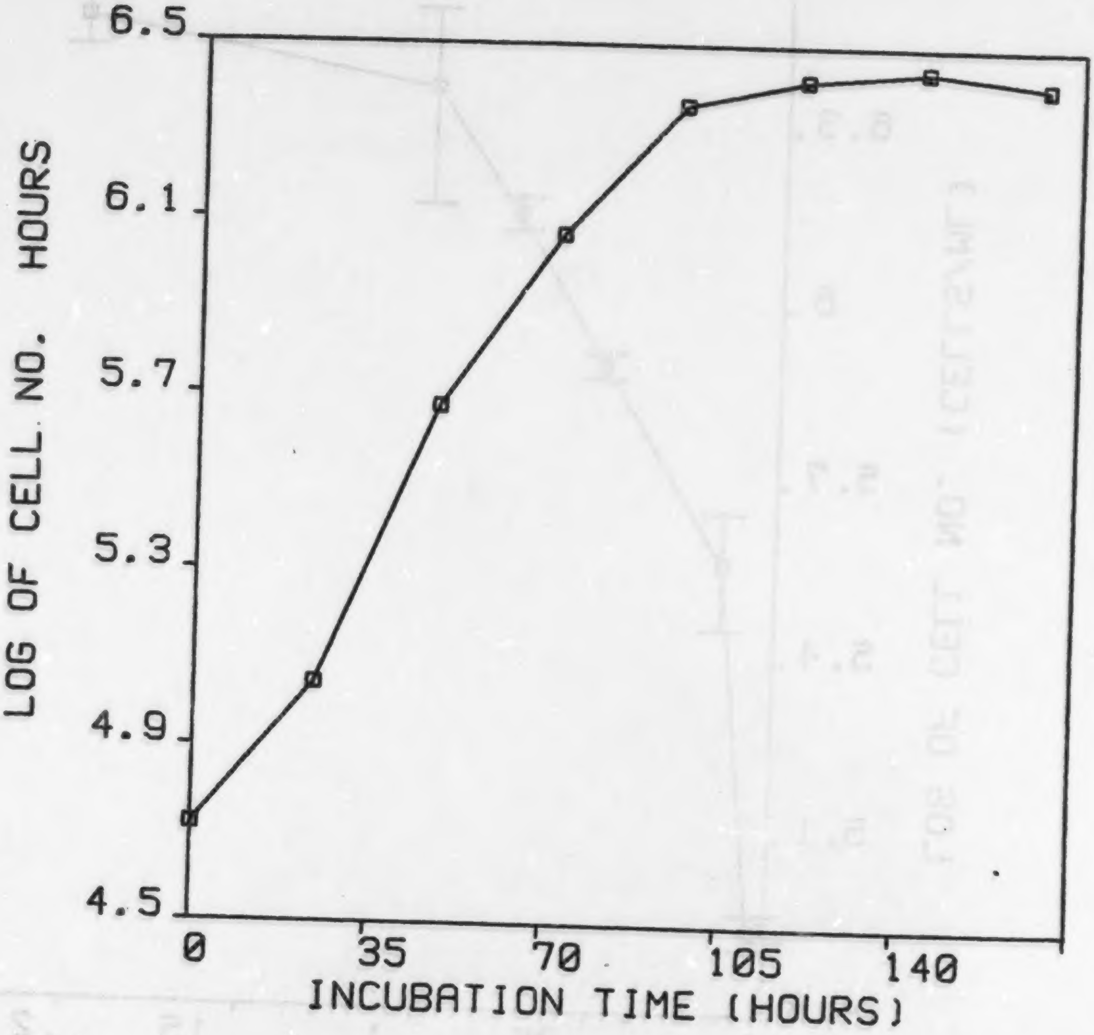

Figure 2. Growth curve of *S. capricornutum* in PAAP medium (0.1 mg P/l).

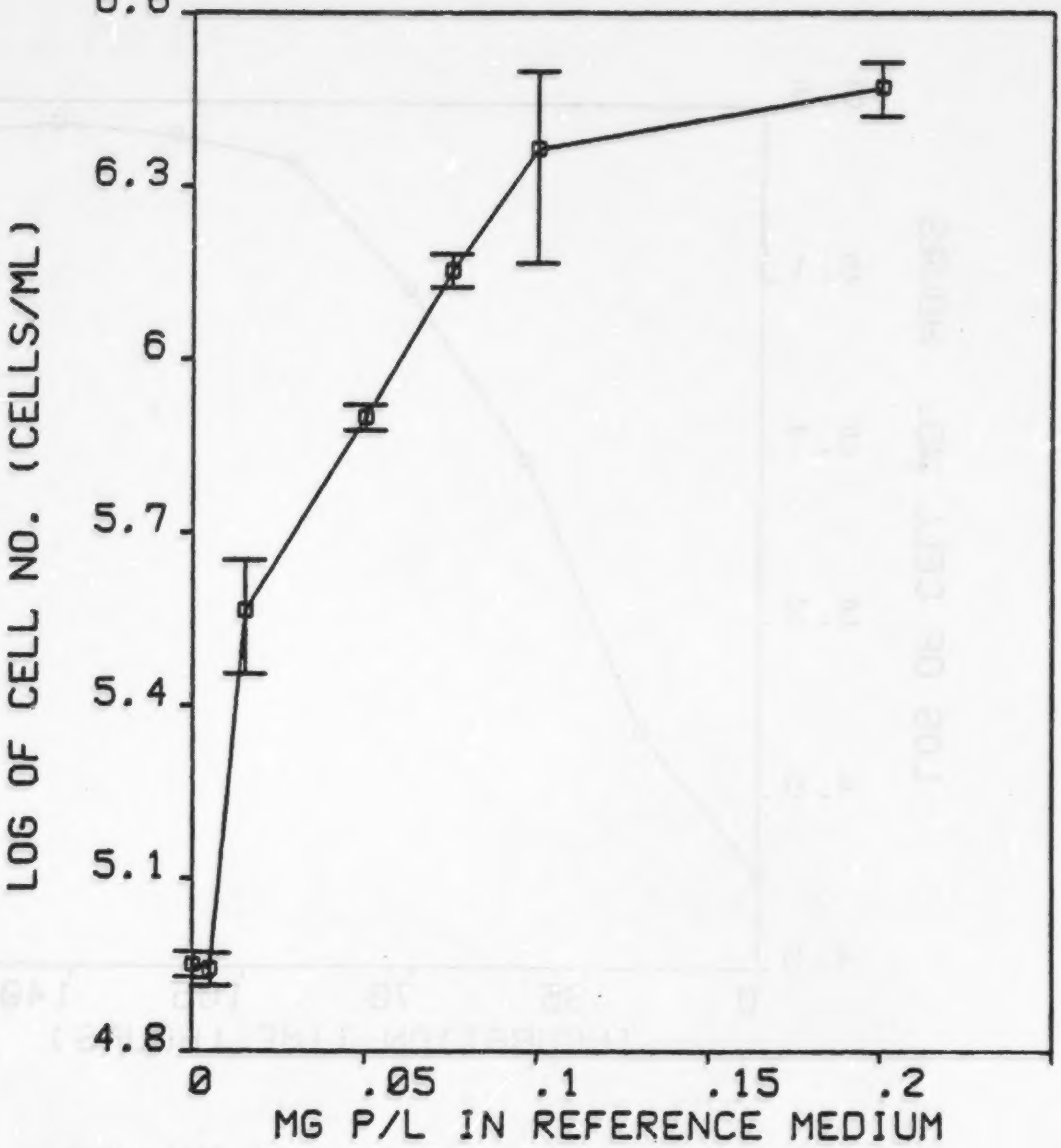

Figure 3. The effect of initial phosphorous concentration on cell numbers of *S. capricornutum* after a four day incubation in PAAP medium. Bars represent the standard deviation of the mean.

did not respond when incubated for four days in PAAP medium containing 0.005 mg P/1. The lack of response at the P level of 0.005 mg/1 and positive response at 0.015 mg/1 suggests that the lower threshold of sensitivity of of the alga for P lies between 0.005 and 0.015 P/1.

Table 1 provides data on the amounts of available P in water samples determined by the algal bioassay procedure (Figure 3) in unamended and spiked water samples. The available P levels in the March and June samples averaged 0.096 (range was 0.076 to 0.128 mg/1) and 0.031 mg/1 (range was 0.012 to 0.052 mg/1), respectively. The available P as quantitated by bioassay never exceeded the soluble inorganic P (SIP) or total soluble P levels in unamended water samples obtained in March and June. Fitzgerald and Uttormark (1974) found that creek water often contains P compounds which are included in chemical determinations as soluble phosphorus, but which are not biologically available.

On the average, P addition did not affect the amounts of algal available P present in the March or June samples. One sample (Site 3) taken in March exhibited a decrease in available P as a result of P addition. Hutchinson (1957) previously has shown inhibition in algal growth upon amendment of water samples with P. In contrast, two P-amended June samples (Sites 3 and 6) contained higher amounts of available P as compared to the unamended samples indicating that growth of S. capricornutum in these samples was limited to an extent by low available P concentrations. In one sample (Site 6), the amount of available P found after P addition was nearly equal to the 0.1 mg/1 critical level suggesting that P was the major factor limiting growth. The addition of P to June samples from Site 3 resulted in slightly increased P availability; however, the response was much less than that expected if growth was only limited by low P concentration.

Table 1. Availability to algae of soluble phosphorous in stream water as affected by initial phosphorous concentration, and phosphorous and micronutrient amendments.

Site no.	Initial P concentration in water		Available P in water as determined from cell count of bioassay of:*		
	SIP	TSP	U**	P	MN
	mg P/l				
March					
2	0.106	0.123	0.080 a	0.084 a	0.097 a
3	0.121	0.150	0.076 a	0.032 b	0.100 a
4	0.121	0.139	0.109 a	0.108 a	0.107 a
5	0.171	0.173	0.128 a	0.105 a	0.106 a
6	0.259	0.443	0.110 a	0.068 a	0.105 a
12	0.135	0.153	0.086 a	0.063 a	0.110 a
14	0.131	0.148	0.083 a	0.095 a	0.128 b
Ave.	0.149	0.190	0.096 a	0.079 a	0.107 a
June					
2	0.069	0.100	0.030 a	0.016 a	0.036 a
3	0.038	0.063	0.015 a	0.031 b	0.016 a
4	0.045	0.075	0.027 a	0.038 a	0.039 a
5	0.053	0.072	0.035 a	0.120 a	0.043 a
6	0.072	0.091	0.045 a	0.094 b	0.039 a
12	0.047	0.171	0.012 a	0.015 a	0.016 a
14	0.161	0.190	0.052 a	0.042 a	0.265 b
Ave.	0.069	0.109	0.031 a	0.051 a	0.064 a

*U, unamended water sample; P, water samples spiked with 0.1 mg P/l; MN, water sample spiked with micronutrients

**Numbers in a row followed by the same letter are not statistically different (at the 0.1 level of significance).

On the average, addition of micronutrients to the growth medium did not affect the ability of algae to utilize P in water samples. However, in two of the fourteen samples a significant increase in apparent available P was observed as a result of micronutrient addition. These results were obtained in both the March and June samples of Site 14 (Maumee River) which suggests that micronutrient deficiencies were limiting the growth of *S. capricornutum* in these samples and addition of the micronutrients enabled the algal cells to better utilize the P which was present. The finding that micronutrient (B, Mn, Zn, Co, Cu, Mo, or Fe) deficiencies may limit the growth of algae in stream waters is supported by Scherfig et al., (1973) who observed limitation of algal growth by low concentrations of iron in similar incubation systems, and by Fitzgerald and Uttormark (1974) who reported that low iron concentrations commonly limit algal growth in surface waters. In addition, other investigators have not been able to detect soluble iron in Black Creek water samples taken during the period from 1975 through 1977 (unpublished data, D. W. Nelson).

Samples taken in March and June from the rural portion of the watershed (the area only affected by agricultural activities) contained lower quantities of available soluble P than did samples from the rural-urban portion (the area affected by agricultural activities as well as septic tanks). Furthermore, for the June period a higher proportion of SIP present in samples from the rural-urban area was available to algae as compared to that present in samples from strictly agricultural areas. However, the proportion of SIP present in Maumee River samples was higher than that in any samples collected within the Black Creek Watershed.

Availability of Sediment-Bound Phosphorus to Algae

Table 2 summarizes the concentrations of suspended solids and P components initially present in the sediment used for bioassay. Although the amount of soluble (desorbed) inorganic P was significant initially (2-4 μg P/flask). Variations in total sediment P recovered initially for each treatment (Table 2) may result from the method used to add the sediment slurry to the incubation flask. The type of suspended material and the difficulty in maintaining homogeneity during the removal of aliquots from the sediment solution concentrate may be additional sources of error. Table 3 provides data on the final cell densities and the proportions of total sediment P immobilized by algal cells from each sample during a two-week incubation in PAAP minus P medium. On the average, the proportion of sediment P which was available for algal assimilation was similar in March and June samples. In March samples, the proportion of total sediment P which was algal available ranged from 9.8 to 29.0% (average 20%), whereas the range in June samples was 15.9 to 30.8% (average 21.4%). These proportions are slightly higher than results reported by Wildung and Schmidt (1973) using lake sediments in a dialysis assay system. There were no apparent relationships between algal cell densities and the proportion of total sediment P assimilated by algae.

The proportion of sediment inorganic P immobilized by algae cells and cell numbers observed after a two week incubation period are presented in Table 4. A higher percentage of sediment inorganic P was available to algae in June samples than in March samples (33.0 as compared to 27.0%, respectively). However, for three of the five sampling sites studied, no difference in avail-

Table 2. Forms and amounts of phosphorous present initially in sediment bioassay samples.

Site no.	Sampling date	Suspended solids	Total P	Sediment inorganic P		Sediment organic P		Soluble P	
		mgs / flask	µg P/ flask	µg P/ flask	% of total[+]	µg P/ flask	% of total	µg P/ flask	% of total
				PAAP-P Medium					
2	March	98	27.31	12.96	47.4	11.86	41.2	2.49	9.1
3	March	119	27.78	13.57	48.8	11.77	42.4	2.44	8.8
4	March	339	29.20	17.47	59.8	9.20	31.5	2.44	8.3
5	March	29	31.33	19.66	62.7	7.98	25.5	2.04	6.5
6	March	25	27.33	15.74	57.6	7.01	25.6	4.58	16.7
12	March	28	28.50	15.26	53.5	10.10	35.4	3.15	11.0
14	March	20	30.81	16.11	52.3	11.06	35.9	3.64	11.8
Ave.	--	94	28.89	15.82	54.7	9.77	33.8	2.97	10.3
				PAAP-P Medium					
2	June	26	30.65	15.07	49.2	11.45	37.3	4.13	13.5
3	June	42	29.00	15.62	53.9	9.44	32.9	3.83	13.2
4	June	36	23.36	13.59	58.2	7.95	34.0	1.82	7.8
5	June	37	26.25	12.00	45.7	11.38	43.4	2.87	10.9
6	June	60	29.11	21.73	74.6	4.92	16.9	2.45	8.4
12	June	50	34.41	19.85	57.7	12.05	35.0	2.51	7.3
14	June	27	27.97	15.61	57.9	7.05	26.1	5.31	19.7
Ave.	--	40	28.53	16.21	56.8	9.19	32.2	3.27	11.5

ability of sediment inorganic P were observed when comparing March samples to June samples. Two June samples (Site 4 and 6) show increases (19 and 7%, respectively) in the percentage of sediment inorganic P which was immobilized into algal cells as compared to results from the March samples. The large increases in inorganic P available in samples from these sites resulted in the average increase when all sites were considered. The average proportions of sediment inorganic P which were available are lower than the 53 to 83% values reported by Sagher and Harris (1975) for lake sediments.

The highest proportion (averaging 37.7 and 46.2% for March and June samples, respectively) of available sediment inorganic P was phosphate sorbed on amorphous Al and Fe oxide complexes (extractable with 0.5 N NH_4F, pH 7). In addition, a significant percentage (averaging 56.2 and 62.3% for March and June samples, respectively) of the NH_4F-extractable fraction of sediment inorganic P was assimilated by algal cells. Significant proportions (averaging 33.1 and 40.8% for March and June samples, respectively) of the available sediment inorganic P were present as iron complexed phosphate extractable with 1 N NaOH. Furthermore, during the two week incubation a substantial percentage (averaging 23.6 and 30.0% for March and June samples, respectively) of the NaOH-extractable P was immobilized into algal cells. A higher proportion of sediment inorganic P was available to algae in samples taken in March and June from the rural-urban portion of the watershed (32.7 and 34.4%, respectively) than in samples from the rural portion (23.2 and 29.9%, respectively). The highest proportion of sediment inorganic P which was assimilated by algae was observed in the Maumee River sample collected in June.

Table 3 Population of *S. capricornutum* and Proportion of Total Sediment Phosphorous Immobilized by Cells Growing for Two Weeks in Sediment:PAAP Systems.

	Sampling time			
	March		June	
Site no.	Cell density	Algal available P	Cell density	Algal available P
	X 10^{-6}/ml	% of total sediment P	X 10^{-6}/ml	% of total sediment P
2	8.529	29.0	5.175	15.2
3	9.599	15.0	8.551	18.0
4	4.242	9.8	5.954	21.5
5	5.225	24.7	5.000	15.9
6	6.500	21.3	6.591	30.8
12	--	--	5.900	20.4
14	--	--	8.408	28.2
Ave.	6.819	20.0	6.511	21.4

Table 4. Population of *S. capricornutum* and proportions of sediment inorganic Phosphorous immobilized by cells growing for two weeks in Sediment:PAAP systems.

	Sampling time			
	March		June	
Site no.	Cell density	Available P	Cell density	Available P
	X 10^{-6}/ml	% of Pi	X 10^{-6}/ml	% of Pi
2	8.529	26.7	5.175	26.7
3	9.599	27.9	8.551	29.0
4	4.242	15.0	5.954	34.1
5	5.225	34.8	5.000	31.1
6	6.500	30.7	6.591	37.7
12	--	--	5.900	32.7
14	--	--	8.408	40.9
Ave.	6.819	27.0	6.511	33.1

IMPLICATIONS

The Black Creek project was in part initiated to evaluate the impacts of agricultural drainage on water quality in the Maumee River and Lake Erie. Therefore, an assessment is required as to the relative impact of soluble and sediment-bound P in drainage water upon the potential for water entering Lake Erie to support algal growth. Numerous assumptions are required to calculate the input of algal available P into the western basin of Lake Erie from the Maumee River watershed. These assumptions are listed in Table 5.

Table 5. Information used in calculating algal available P discharge into Lake Erie from the Maumee River.

Parameter	Value	Citation
Sediment loads of Maumee River	495 kg/ha	Monke *et al*. (1975)
Water discharge from Maumee River watershed to Lake Erie	23 cm/yr	Monke *et al*. (1975)
Maumee River Watershed area	1,711,500 ha	Monke *et al*. (1975)
SIP Concentration in Maumee River water	0.076 mg P/l	Sommers *et al*. (1975)
Total P Concentration suspended sediment	1990 mg/kg	Sommers *et al*. (1975)
Volume of water in western basin of Lake Erie	70 km^3	Blanton and Winklhofer (1972)

As indicated by the information in Table 5, the total amounts of sediment and sediment-bound P discharged to Lake Erie by the Maumee River average 847,000 and 1,685 metric tons per year, respectively. Assuming 20% of the total sediment P is ultimately available to algae (as found in this study), approximately 337 metric tons of available P will be discharged with sediment loads each year into Lake Erie.

Approximately 3.94×10^{12} l of water containing 299 metric tons of SIP are discharged into Lake Erie each year from the Maumee River. The SIP discharge value is based upon a SIP concentration of 0.076 mg/l, the average level measured in numerous water samples collected at Site 14 (Figure 1). It is possible that the SIP concentration in the Maumee River watershed entering Lake Erie is lower than that measured at Fort Wayne, Indiana, however, no information was available to adjust the SIP concentrations used in the calculations. Assuming that 50% of the SIP is available to algae (as was found in this study), about 150 metric tons of available SIP are discharged to Lake Erie annually.

Considering both soluble and sediment-bound P forms, approximately 487 metric tons of algal available P are discharged into Lake Erie each year. These calculations suggest that sediment-bound and soluble P provide 69.2 and 30.8% of the P available to algae in Maumee River discharge, respectively. It is unlikely that the concentration of SIP in agricultural drainage water can be reduced below 0.06 mg/l, therefore control of soil erosion (sediment input into streams) is essential to lower amounts of algal available P discharged into surface waters of midwestern United States.

The above approximations of P inputs into Lake Erie from the Maumee River can be used to estimate the impact of the Maumee River on the concentrations of soluble, sediment-bound, and available P in the western basin of Lake Erie. The estimate made herein also uses the following assumptions: (i) The phosphorus inputs (both soluble and sediment) from the Maumee River becomes uniformly distributed throughout the volume of the western basin of Lake Erie, (ii) The volume of the western basin of Lake Erie is 70 km^3 (Blanton and Winklhofer, 1972) and (iii) All P entering Lake Erie is retained during the year. Under these conditions, the estimated increases in concentrations of SIP, available SIP, sediment P, and available sediment P in the western basin of Lake Erie after 1 year would be 3.9, 2.0, 26.2, and 5.2 μg/l, respectively. These increases in available P concentrations may result in significant increases in algal growth when initial available P levels in water are 25 μg/l or less. At high initial P concentrations, algal growth would be influenced to a limited extent by these increases in available P. Furthermore, not all of the added available P will be utilized by aquatic plants because the water in Lake Erie has a short residence time with the annual flow through the Lake being equal to 1/3 of the Lake volume.

CONCLUSIONS

The following conclusions may be drawn from data obtained during this study:

(1) Not all of the soluble P in water samples was available to algae. The level of soluble P available to algae never equalled the SIP or total soluble P concentration in any of the 14 samples collected from the Black Creek Watershed or the Maumee River. In samples containing less than 0.1 mg SIP/1, only about 50% of the soluble P in water samples was available for algal uptake.

(2) A deficiency of one or more micronutrients limited algal growth in water samples collected from the Maumee River. If this deficiency persists throughout the length of the Maumee River, algal growth rates in the western portion of Lake Erie may be lower than predicted by P loading data.

(3) Sediment in agricultural drainage water contained substantial concentrations of algal available P. Excellent algal growth was observed in media with sediment as the only source of P. However, maximal algal growth rates (as compared to PAAP) were not achieved in PAAP minus P media containing sediment. On the average, 20% of the total sediment P and 30% of sediment inorganic P were available for algal uptake.

(4) Phosphate loosely sorbed on amorphous Al and Fe oxide complexes supplied the highest proportion of P assimilated by algae. A higher proportion of the quantity of the P originally present in the amorphous Al and Fe oxide complex was taken up by algae than in the other fractions investigated. The quantity of P loosely sorbed on amorphous Al and Fe oxide complexes is most important in determining the overall availability of sediment P to algae.

(5) Intensive crop production systems did not lead to increased availability of soluble and sediment-bound P in drainage water when compared to Maumee River water. Higher availability of P to algae was measured in water samples collected from the Maumee River and portions of the watershed influenced by septic tanks as compared to samples collected from agricultural portions of the watershed.

(6) A greater quantity of algal available P is discharged annually to Lake Erie as sediment-bound P than is discharged as soluble P. This finding suggests that erosion control measures in the watershed which would lead to reduced sediment discharge into Lake Erie may result in decreased algal growth in the western basin.

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Tile Drainage: Will Best Management Practices Increase or Decrease Loadings to the Maumee River?

By A. B. Bottcher

The increasing interest in the water quality of our lakes and streams has prompted a number of groups to propose the use of Best Management Practices (BMP's) to correct the water quality problems. The majority of the BMP's being suggested are geared at reducing the sediment loadings from surface runoff. This is a reasonable approach since data indicates a large percentage of the total nutrient load (50 and 80 percent for N and P, respectively) is associated with the suspended solids in the water (Lake and Morrison, 1977). A large number of the suggested BMP's such as: contour cropping and tillage, minimum tillage, terracing, grassing drainage ways, etc., are the same as those already recommended for soil conservation. Therefore, by careful planning, both water quality and soil conservation may be addressed at the same time thereby eliminating a duplication of effort. However, the question still remains - to what extent the soil conservation BMP's will affect water quality.

Many are confident that these BMP's will reduce sediment yields and therefore the sediment-associated nutrients, but the degree of improvement we can expect and the extent the non-sediment-associated nutrients will be affected are not well understood. To address these questions, one must first understand the hydraulic and hydrologic influences of the BMP's and then try to quantify the water quantity and quality impact of such a system.

The soil conservation BMP's use a simple principle, namely, reduce the water flow rate and the erosion rate will be reduced accordingly. However, the decreased water flow rate will provide additional time for infiltration which increases total infiltration volume. This increased infiltration could result in some potential problems, (1) reduced productivity due to wetter soil conditions in poorly drained areas, (2) increased water yield from subsurface drainage systems which are typically high in nitrate and (3) increased nitrate leaching in well-drained areas.

This paper will look at both the problems and benefits associated with the increased infiltration resulting from the reduction of surface runoff. A comparison between a surface runoff site (Smith-Fry) and a no surface runoff site (tile drained) will be used to quantify the effect of an "ideal" soil conservation BMP on nutrient and sediment losses. It should be noted that the "ideal" BMP refers to the elimination of surface runoff and not to the tile drainage system. The drainage system is used simply to maintain crop productivity.

Site Descriptions

The surface runoff site is the Smith-Fry subwatershed (942 hectares) in the Black Creek study area. The watershed is approximately fifty percent tile drained. However, tile drains only yield about fifteen percent of the total runoff. The soils are predominantly flat lake bed and beach ridge formations with the major soil type being Hoytville silty clay. There are only a few houses in the Smith-Fry drainage area, so domestic influences are minimal. The majority of the area is in row crops or small grains and pasture (63 and 26 percent, respectively). The flow and concentration data was taken at the outflow point of the watershed on the Smith-Fry drain.

The no surface runoff site is a seventeen hectare field which is underlayed with subsurface tile lines. The field borders are raised to prevent surface runoff from this nearly flat lake bed soil. The predominant soil type is a Hoytville silty clay with the remainder soil type being Nappanee. The flow and concentration data was collected at a single thirty centimeter tile outlet which represented the total runoff from this site.

Data Collection

Water quality and flow were determined at both sites by using automatic samplers and weir-stage recorders, respectively. The samplers were capable of collecting seventy two 500 ml water samples before servicing was required. The sampling rates were 1 sample per 1/2 hour (Smith-Fry) and varied proportional to flow between 1 sample per 40 minutes to 1 sample per 12 hours for the tile site. Weekly grab samples were collected on the Smith-Fry drain to provide water quality data during periods of low flow. The Smith-Fry sampler was event activated. Collected samples were frozen within twenty-four hours to limit chemical transformations prior to laboratory analysis.

Bubble-tube stage recorders were used to measure water depth just upstream of flow calibrated weirs. A stage-flow relationship for each weir was then used to determine flow from the stage records. The tile drain required a pump-sump arrangement to assure a free fall over the weir. Rainfall was also recorded at both sites.

Results and Discussion

Water Yield

The water yield (reported as equivalent depth to eliminate area differences between sites) was significantly lower (61%) for the tile drained field (no surface runoff) than the Smith-Fry drain (surface runoff) as can be seen in Table 1. This indicates that a large portion of the "would be" surface runoff for the tiled site was stored in the soil profile for later evapotranspiration. The benefits of this water storage was evident by the very good crop stand observed on the tile site during the dry year of 1976. In 1976 almost ten centimeters of water or eighty nine percent of the total runoff from the Smith-Fry drain could have been prevented if surface drainage had been reduced. The wet condition during the first seven months of 1977 resulted in a smaller water yield difference (31%) between the two sites. This

Table 1. Water Yield and Rainfall for the Smith-Dry (Stream) and Tile Sites.

Component	1976 Stream	1976 Tile	1977* Stream	1977* Tile
	cm			
Water Yield	11	1.2	10	6.9
Rainfall	70	66	46	46

*Through 7/7/77

follows since available water storage decreases with increased soil moisture content. The water yield difference for the entire year of 1977 is expected to be much higher since the tiles flow mainly during the spring.

The reduction of total runoff will have a direct impact on the sediment and nutrient loadings, since loads are determined by the multiplication of flow rate and concentration. This means that even if the concentration of a constituent remains the same or even increases slightly, a loading reduction of that constituent may still be realized. This emphasizes the potential hazard of using loading data for instream water quality impact. In general, loadings should be used when addressing the impact of a water source on a receiving water body and concentrations used for instream water quality impact.

Sediment and Nutrients

Table 2 gives a summary of the sediment and nutrient loading data collected for one year and seven months. The stream data refers to the Smith-Fry drain. A comparison of the stream and tile sites will give an idea of the extent water quality may be affected by an "ideal" soil conservation BMP. As can be seen in Table 2, the only time loadings were not significantly

Table 2. Sediment and Nutrient Transported

Component	1976 Stream	1976 Tile	1977* Stream	1977* Tile
	kg/ha			
Sediment	640	21	180	54
Sol Inorg P	.06	.002	.07	.05
Sol Org P	.03	.005	.03	.02
Sediment P	.98	.02	.75	.14
Ammonium N	.6	.01	.42	.27
Nitrate N	5.5	.68	8.5	11
Sol Org N	.31	.05	.16	3.1
Sediment N	3.9	.11	1.8	.65

*Through 7/7/77

lower for the tile drainage system was in the wet spring of 1977 and then it was just nitrate and soluble organic nitrogen which increases. The high nitrate level would be expected because of the higher comparative water yield coming from the tile system. However, the soluble organic nitrogen was unusually high as the result of a seven centimeter rainfall just after a surface application of nitrogen in the form of urea. Nitrogen in this form would normally be mineralized and de-nitrigied within five to six days. This is evident in Figure 1 where the soluble organic nitrogen concentration quickly decreases after the April 19th surface application or urea. Also the urea usage on the Smith-Fry watershed was much lower on a per hectare basis.

The sediment and nutrient concentrations as reported in Table 3 were not consistently lower for the tile drainage water as were the loading results. Sediment and sediment associated nutrients were lower as would be expected since surface erosion was eliminated. Ammonium N was also slightly lower

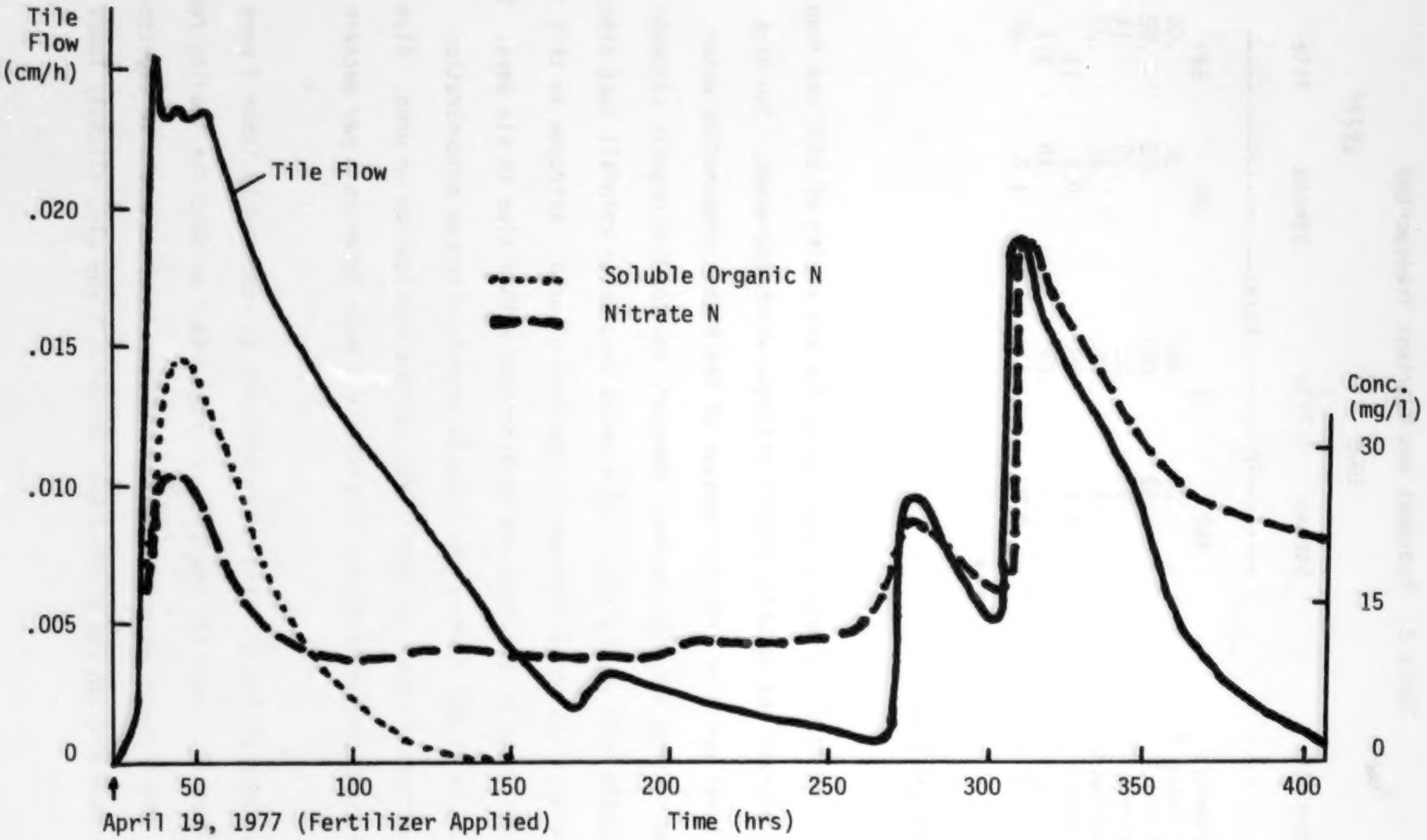

Figure 1. Soluble Organic N and Nitrate N Concentrations vs Time Shortly After Surface Application of Urea.

Table 3. Concentration of Transported Sediment and Nutrients

Component	1976		1977*	
	Stream	Tile	Stream	Tile
	mg/l			
Sediment	520	170	180	78
Sol Inorg P	.05	.02	.07	.07
Sol Org P	.03	.04	.03	.03
Sediment P	.79	.22	.74	.20
Ammonium N	.48	.09	.41	.38
Nitrate N	4.5	5.6	8.3	15
Sol Org N	.25	.44	.15	4.5
Sediment N	3.2	.92	1.8	.93

*Through 7/7/77

because this monovalent cation is easily absorbed in the cation exchange complex (CEC) before reaching the tile drain. The concentration of the soluble forms of phosphorus did not vary significantly between the two sites and nitrate and soluble organic nitrogen concentrations actually increased for the tile system.

Table 4. Percent difference in loadings and concentrations of sediment and nutrients between the stream and tile drain data compared to the stream data.

Component	% Change					
	1976		1977*		Weighted Average	
	Loading	Conc.	Loading	Conc.	Loading	Conc.
Water	-89	-	-31	-	-61	-
Sediment	-97	-67	-70	-56	-91	-74
Sol Inorg P	-97	-60	-28	0	-60	+5
Sol Org P	-83	+33	-33	0	-58	0
Sediment P	-98	-72	-81	-73	-91	-74
Ammonium N	-98	-81	-35	-7	-42	-25
Nitrate	-88	+24	+29	+80	-17	+115
Sol Org N	-84	+76	+1800	+2900	+680	+1800
Sediment N	-97	-71	-64	-48	-87	-63

Table 4 gives a clearer picutre of the actual water quality differences which may be incurred if surface drainage is reduced to near zero. It is easy to see that a high percentage of the reduction in sediment and nutrient loadings can be associated with the reduced water yield.

Summary and Conclusions

A comparative study was done to estimate the potential impact of implementing an "ideal" soil conservation BMP. The comparison was made between a "typical" watershed condition for the Maumee River Basin and tile drained field which had essentially no surface runoff. The land use and soil types were similar between the two selected sites. Based on the results of the study, the following conclusions were made:

1. BMP's which will reduce surface erosion may significantly reduce water, sediment and nutrients loadings to a receiving stream.
2. Sediment and sediment associated nutrient concentrations will be significantly reduced by the reduction of surface erosion.
3. The concentration of soluble forms of phosphorus will not be significantly different if surface erosion is reduced.
4. Nitrate concentrations in runoff are significantly increased by forcing drainage water through a soil profile. Concentrations of soluble organic nitrogen may also be higher, but it is highly dependent on fertilizer application (type and timing).
5. Timing of a fertilizer application can have a significant impact on the annual loading rates of nitrogen. Phosphorus has less of a response to fertilizer application.
6. Water storage in the soil profile, which is later lost through evapotranspiration, is the mechanism that accounts for the water yield reduction gained by a low surface runoff system.

7. The additional water storage provided by the zero surface runoff - tile drained system may increase crop productivity during dry periods.
8. The need for tile drainage may increase as more soil conservation BMP's are implemented.

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RESULTS OF A VOLUNTARY PROGRAM OF LAND MANAGEMENT TO IMPROVE WATER QUALITY

by

James B. Morrison

For the past four years, investigators from the Black Creek project have been making reports of scientific findings resulting from the study of a 12,000-acre watershed in Northeastern Indiana. Reports have been previously presented today summarizing some of this information. This report is concerned primarily with the voluntary participation of landowners in the Black Creek watershed and does not concentrate on vast quantities of technical data. Data is available in the Black Creek technical volume covering all aspects of the project.

Much of the information presented in this report is admittedly subjective. However, it has been the experience of many persons involved with the Black Creek project that this type of subjective information is useful when planning programs to improve water quality.

The subjective nature of this report is indicated by the three questions it addresses:

1) Were the voluntary aspects of the project a success and why or why not?

2) Was the information gained from the project useful from an administrative standpoint?

3) What do the Black Creek cost figures mean?

WAS THE PROJECT A SUCCESS?

I suppose there is a tendency to point to areas in which a success is claimed with a certain amount of pride and to simultaneously cite areas which were not so successful as instances in which "we learned something."

There is an opportunity to make both of these comments about the Black Creek project.

There are many ways in which success of the project could be measured:

Was there adequate participation by the landowners?

Did participation involve actions that would meet the goals of the project?

Did the project result in an improvement in water quality in the Black Creek?

Table 1 gives some indication about participation. As can be readily seen from this table, most landowners in the Black Creek watershed participated in the project. In all, 141 out 148 potential cooperators decided to take part. That is 95 percent and can be fairly counted an indication of good participation. Notice, however, as we move on down the table, that 95 percent participation did not automatically mean that 95 percent of the other goals of the project would be reached. In some instances, more than 100 percent of the goal was reached; in other instances, none of the goal was accomplished.

There are several reasons for this disparity. A major one may have been an unrealistic establishment of goals. This comment is not intended as a criticism of the original planning. However, it is obvious that there were items in the original plan for which there was just no place in the Black Creek watershed.

Another reason was the changing focus of the project as it was carried out. This resulted in emphasis being given to some practices at the expense of others as it became more clear in the minds of project administrators and the Soil and Water Conservation District Board of supervisors which practices were most likely to have a beneficial impact on water quality.

Finally, however, and probably equally important to the other two reasons, was the way in which landowners viewed the project. Subjectively, it can be stated that very few landowners were hostile to the idea of water quality improvement. Probably those landowners who did not participate in the project represent an accurate measure of the number who were hostile to the idea of utilizing land management techniques for environmental improvement. On the other hand, most landowners did not initially elect to participate in the project with a primary goal of improving water quality. It is no secret that the major limitation on the use of land in the Black Creek project for agricultural purposes is drainage. Landowners in this situation tend to see soil conservation as a means of improving drainage. Many therefore approached the project with an idea of getting help on drainage improvement. Since the agreements between the district and the landowners were purely voluntary, this bias toward improved drainage shows up in the final amounts of various practices that were installed.

Table 1. Goals and Accomplishments

PRACTICE	UNIT	GOAL	ACCOMP-LISHMENT	% OF GOAL ACCOMP
District Cooperators	No	148	141	95
Conservation Plans	No	170	133	78
Landowner-District Contracts	No	148	119	80
Group Contracts	No		19	
Land Adequately Treated	Ac	10,573	7,975	75
Land Adequately Protected	Ac		10,025	
Conservation Cropping System	Ac	7,418	6,548	88
Contour Farming	Ac	769	10	1
Critical Area Planting	Ac	10	15	150
Crop Residue Management	Ac	7,491	2,952	39
Diversions	Ft	39,200	1,860	5
Farmstead Windbreaks	Ac	75	4	5
Field Border	Ft	288,320	132,688	46
Field Windbreak	Ft	12,000	0	0
Grade Stabilization Structure (including tile outlet CMP)	No	368	516	140
Grassed Waterway	Ac	68	64	94
Holding Ponds & Tanks	No	11	10	91
Land Smoothing	Ac	300	0	0
Livestock Exclusion	Rd	2,050	15,869	78
Livestock Watering Facility	No	28	7	25
Minimum Tillage	Ac	7,656	688	9
Pasture Management	Ac	402	97	24
Pasture Planting	Ac	501	112	22
Pond	No	39	10	26
Protection During Development	Ac	118	4	3
Recreation Area Improvement	Ac	12	10	83
Sediment Control Basins	No	6	3	50
Stream Channel Stabilization	Ft	6,000	16,093	268
Streambank Protection	Ft	122,000	99,304	81
Stripcropping	Ac	300	0	0
Surface Drains	Ft	90,500	9,396	10
Terraces	Ft	22,000	51,553	234
Tile Drains	Ft	200,300	134,316	67
Tree Planting	Ac	10	0	0
Wildlife Habitat Management	Ac	222	148	67
Woodland Improved Harvesting	Ac	200	0	0
Woodland Improvement	Ac	610	0	0
Woodland Pruning	Ac	50	0	0
TOTAL (WATERSHED)	Ac	12,038		

In fact, there has been criticism of the Black Creek project on the basis that too much money was spent for channel reconstruction measures and measures related to drainage. As is discussed in more detail later, project administrators now believe that an equal degree of land treatment could have been achieved for less money if many practices in which cost sharing was offered had been eliminated from the original plan.

This analysis however, overlooks the simple fact that it is unlikely that 95 percent or even 50 percent of the landowners in the watershed would have participated in a voluntary program if practices that related to their desires -- such as the desire for improved drainage -- had not been recognized by project administrators.

Let me make it clear at this point that I am not saying that cost sharing was offered on the Black Creek project for tile drainage, per se. Tile drainage was included, however, in connection with practices such as grassed waterways, and drainage improvement was a result of channel reconstruction and stabilization work.

The following conclusion is suggested: The Black Creek project was successful in gaining cooperation, was less successful in accomplishing land treatment that would have as a primarily result the improvement of water quality, and achieved the success that was obtained by harmonizing the desires of landowners to simplify or improve their farming operations with the desire of project personnel for measures that would result in improved water quality.

WAS THE INFORMATION USEFUL?

One of the primary conclusions reached by the Black Creek project was that rather substantial improvements in water quality could be achieved by concentrating efforts on selected "critical" areas rather than aiming at broad treatment of vast areas of land.

It has been suggested that this conclusion is so obvious that it was not necessary to conduct a project to learn it. The conclusion does seem obvious and is a point expressed by Indiana's Governor Otis Bowen in his charge to the state's new water resources planning commission this way:

"If it ain't broke, don't fix it."

The idea of concentrating land treatment efforts only on critical areas, however, has not been a part of the philosophy of soil and water conservation programs in the United States. Rather, the thrust has been to attempt to treat every acre of land on cooperating farms so as to fulfill all of the conservation needs.

Simultaneously, there has been a desire to assure broad participation in Soil and Water Conservation programs by establishing rigid cost sharing rates and by putting a limitation on the amount that one landowner could receive in any one year from federal conservation programs.

The Black Creek finding that efforts should be concentrated on critical areas when the primary purpose is water quality runs counter to these policies. If you carry the recommendation for concentration on critical areas to its logical extreme, we are saying that if the goal is to improve water quality, and funds have been made available for this purpose, and if we discover that the maximum benefit in water quality could be achieved by spending all of the money appropriated for an area on only one or two farms in that area, then the water quality funds should be spent only on those farms.

Soil and Water Conservation programs in the past have not concentrated on water quality to the exclusion of other desirable goals. The Black Creek project has identified four distinct positive aspects to soil and water conservation programs:

1) Those which have as a primary result the improvement of water quality.

2) Those which have as a primary result the protection of the soil resource.

3) Those that have as a primary result the enhancement of agricultural production.

4) Those that have as a primary result some other conservation purpose. (Including better woodland management, improved wildlife habitat, enhanced recreational opportunities, etc.)

Nothing in the findings of the Black Creek project indicates that any one of these purposes is not a worthwhile purpose. Certainly, the soil resource must be protected, certainly enhanced agricultural production is important to society, wildlife habitat improvement is worthwhile as are better recreational opportunities.

Ideally, water quality improvement would be obtained as a result of treating every acre of land so as to maximize all four of these potential benefits. However, it is highly unlikely that this type of broad program can be applied with the manpower and financial resources available within a time schedule that would satisfy the accelerated goals of Section 208 planning.

The finding that water quality improvement can be obtained in the most cost effective manner by concentrating on critical areas is therefore not trivial, because it implies a rather significant change in traditional soil and water conservation and cost sharing policy. It does not suggest that the old policy is wrong in the long run, but does say that it is not appropriate if accelerated efforts are to be aimed at fulfilling only one of the four benefits of soil conservation. That is a useful result.

In the Black Creek technical report some attention is paid to the way that money was spent in the Black Creek project. Keeping in mind that the Black Creek project was conceived as a program to improve water quality, we now find that more money was spent on programs to fulfill other conservation purposes than was spent on practices that had as a primary result the improvement of water quality -- we would say that only $54,000 was spent for water quality alone, while $430,000 was spent on other practices. This may have been one of those instances in which we learned something. In fact, in the Black Creek area, it was discovered that a very effective way to deal with the problem of sediment was through the encouragement of tillage systems which would leave surface cover and promote surface roughness. Where tillage is adapted, a decision to use a reduced tillage system will usually not result in a yield penalty for corn and may not result in a yield penalty for soybeans. More complete discussion of these points is included in the technical volume of the Black Creek report. The following observation is, however, pertinent. Some 208 planners have apparently been reluctant to consider tillage as a Best Management Practice because of the real or imagined difficulty inherent in determining whether landowners are "in compliance." If it is granted that the monitoring of nonstructural practices, such as changes in tillage, may be harder to readily observe than structural methods such as grassed waterways or terraces, or field borders, this is still not a good reason to eliminate management practices from Section 208 plans. To do so would be to eliminate some or the most effective erosion control measures in the name of administrative convenience.

WHAT DO THE COST FIGURES MEAN?

Black Creek cost data, which has been coming out for the past three years, has been controversial. Some have used it to attempt to prove that nonpoint source pollution control is not a realistic possibility. Others have used it to suggest that the Best Management Practices approach is too costly to be seriously considered.

The project, and the project's writer and editor must take a large share of the responsibility for this "misinterpretation" of the cost data. Now, having seen the results of some of our earlier presentations, we quickly say that it is misleading to take the cost of land treatment, divide that by the number of acres in the Black Creek watershed, and obtain a per acre figure that can be used in projecting costs. Unfortunately, that is the kind of approach that was used in some of our earliest reports. The project reported cost figures that way for the same reason that others have analyzed cost figures in that way, it is convenient and it is easy to do. We now think the following approach is much more reasonable because of the following points:

1) The project was experimental, some practices were applied in ways that later proved not to be the most cost effective.

2) Practices were applied and received cost sharing that it was later determined did not have major impact on water quality.

At the close of the project, we looked backward, and estimated how much of each of the practices which had been identified as best management practices should have been applied to obtain best treatment from the standpoint of water quality. These amounts are included in Table 2.

Table 2. Estimated Treatment Needs At Beginning of Project

Practice	Amount Needed
Field Borders	40 miles
Holding Tanks	10
Sediment Basins	6
Critical Area Planting	10 acres
Grassed Waterways	68 acres
Livestock Exclusion (fencing)	15,000 feet
Pasture Renovation and Planting	400 acres
Terraces	44,000 feet

Table 2 does not include alterations in tillage, because we at this point do not assign a cost to this practice.

Project records were consulted to determine what the actual cost of installation of the listed practice were in the Black Creek project. These results are included in Table 3.

Table 3. Project Installation Costs

Practice	Unit	Cost
Field Border	Mile	1,584
Holding Tanks	Each	5,600
Sediment Basins	Each	5,000
Contour Farming	(1)	(1)
Critical Area Planting	Acre	400
Crop Residue Management	(2)	(2)
Grassed Waterways	Acre	1,200
Livestock Exclusion (fencing)	Foot	0.50
Reduced Tillage	(3)	(3)
Pasture Renovation and Planting	Acre	100
Terraces	Foot of terrace (with tile)	1.75

(1) very little application in Black Creek Area or Maumee Basin.
(2) can be applied by management techniques without additional cost.
(3) considered only on soils where reduced tillage should not result in significant yield penalties.

Now, it simply remains to multiply the amount needed by the cost to get an estimate of what it would have cost to apply the needed practices in the watershed. This is done in Table 4.

Notice that this is less than half of the $719,000 actually spent in Black Creek and note that a much higher percentage of the funds spent would have gone for water quality improvement. However, a word of caution. It is highly unlikely that using a voluntary program, anything approaching these amounts could have been spent in the Black Creek project, because concentration on this list of practices would have eliminated several of the items that most interested landowners at the beginning of the project.

Now, to go really out on a limb. Let's make the same kind of estimates for the Maumee Basin. These estimates are included in Table 5. This is a significant amount of money, certainly, but it is less than one-third of some of the treatment estimates based on Black Creek project results.

Table 4. Estimated Cost of Black Creek Treatment

Practice	Cost
Field Border	63,360
Holding Tanks	56,000
Sediment Basins	30,000
Critical Area Planting	4,000
Grassed Waterways	81,600
Livestock Exclusion (fencing)	7,500
Pasture Renovation	4,000
Terraces	77,000
Total	323,460

Table 5. Estimated Cost of Treating Maumee Basin

Practice	Cost
Field Borders	43,700,000
Holding Tanks	4,480,000-5,600,000
Sediment Basins	7,000,000-10,500,000
Critical Area Planting	1,000,000-1,400,000
Grassed Waterway	19,200,000-28,000,000
Livestock Exclusion	1,300,000
Pasture Planting	10,000,000
Terraces	21,000,000-26,250,000
Total	107,480,000-126,250,000

Funding Support Needed for Nonpoint Source Pollution Control

By

CARL D. WILSON

The impact of agriculture on the nation's water is highly significant as over 950 million acres of land are used for agricultural and closely related purposes. About 387 million acres are used for crop production.

The present trends in agriculture involve employing modern techniques at ever increasing levels of complexity for the use of fertilizers, pesticides, irrigation systems and confined animal feeding facilities. A natural result of these trends will be an increased potential for nonpoint source water pollution of both ground and surface waters. Preventing water quality degradation must become a major concern of the 208 water quality planning and the agricultural community.

About 2 billion tons of livestock wastes are produced annually. As much as 50% of these wastes may be produced in feedlots. While most of these waste materials are confined and eventually spread on farm acreage, runoff and seepage from these sources pose a significant pollution hazard.

Commercial fertilizers consumed during 1972 amount to about 41 million tons. Some of these nutrients are transported, together with naturally occurring nutrient elements, to surface and ground waters.

Pesticides are designed to be lethal to target organisms, but many are toxic to nontarget organisms. Four major categories of importance to agriculture are insecticides, fungicides, herbicides, and rodenticides. Of nearly one billion pounds of pesticides applied in the United States during 1970, about 70% was for farm use. It is anticipated that the use of pesticides will increase tenfold within the next twenty years.

The U.S. Environmental Protection Agency has spent 13.3 billion dollars on conventional sewage treatment plants to date. The President is asking Congress for 45 billion more dollars for the next ten years to address the same problem, point source pollution. Yet the fact remains of the total point, and nonpoint source loadings of 158 million pounds per day of suspended solids, nonpoint source loads will account for 145 million pounds or 92% of the problem.

The logic to continue to increase the funding for point source and neglect the nonpoint source contribution is not justified.

To further justify increased funding for nonpoint source pollution, one can use the total daily nitrogen loading of 35.7 million pounds, nonpoint sources will contribute 28.3 million pounds or 79 % of the problem. Using this ratio, Congress could justify dividing funds using 80% for nonpoint and 20% for point.

Additional facts indicate that nonpoint sources will provide 1.93 million pounds of phosphorus from a total of 3.63 million pounds or 53% of the problem.

For fecal and total coliform counts, nonpoint sources will account for over 98% of the remaining national loadings.

Zinc accounts for a total of 119,000 pounds per day and nonpoint sources contributes 51,000 pounds or 43% of the problem.

In 1967, the World Health Organization estimated that more than one hundred fifty diseases were transferrable between animal and man. Without a doubt, the potential exists for pathogen contamination of swimming and drinking waters when animal or their wastes can reach them.

The significance of these data indicate that nonpoint source problems will prevent the attainment of 1983 goals for water quality.

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